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Disclaimer

This resource is provided to support the teaching and learning of GCSE Computer Science. The materials provide an introduction to the main concepts of the theory of the subject and should be used in conjunction with other resources and sound classroom teaching.

It is intended that the resource will be updated periodically due to the evolving nature of the subject. Tips on how to further develop the materials are welcome. You can send us your tips via our feedback system or by emailing: resources@wjec.co.uk

Contents

Unit 1

1. Hardware

Central Processing Unit (CPU)

To a computer, the world consists of zeros and ones. Inside a processor, we can store zeros and ones using transistors. These are microscopic switches that control the flow of electricity depending on whether the switch is on or off. The transistor, therefore, contains binary information: a one if a current passes through and a zero if a current does not pass through.

Transistors are located on a very thin slice of silicon. A single silicon chip can contain thousands of transistors. A single CPU contains a large number of chips. Combined, these only cover a couple of square centimetres, but can hold several million transistors and process hundreds of millions of instructions per second.

CPU architecture

CPU architecture is a term that refers to the design of a Microprocessor, an integrated circuit, where the components of the CPU are combined as a single unit.

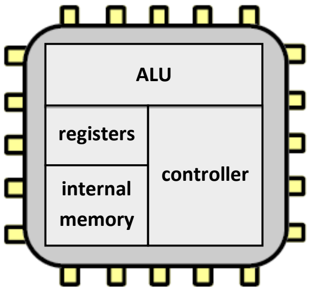
Von Neumann

Early computers were generally designed to carry out a specific task or calculation. Re-programming these custom built computers was very difficult and could even involve some re-wiring. In 1945 John von Neumann proposed the idea of storing the program instructions in the same memory as the data. This idea of a **stored program** resulted in computers that could be more easily re-programmed and is the basis for the fetch-decode-execute cycle (FDE), fundamental to modern computer processing. The idea of a stored program is often referred to as 'Von Neumann' architecture.

Components of the CPU

The CPU is the main component in a computer for processing data and instructions. It could be considered as the computing equivalent of the human brain. It is a hardware device that is made up of many subcomponents:

- controller
- Arithmetic and Logic Unit (ALU)
- registers
- internal memory.



All these components have their own specific function.

Controller or control unit

The controller sends and receives signals from all parts of the computer. It ensures that all processes take place at the right time and in the correct order.

Arithmetic and Logic Unit (ALU)

The ALU is the part of the CPU that processes and manipulates data. It performs simple calculations on the data that is temporarily stored in the registers.

The ALU is also able to perform comparisons on data. It is these comparisons that allow programs to make use of choice – e.g. an IF statement in a high-level language.

Registers

A register is a storage location found on the CPU where data or control information is temporarily stored. Registers are usually much faster to access than internal memory, since they have to be accessed so often.

An accumulator is a common example of a register. This is the register used by the ALU to store the results of its calculations.

SUMMARY OF DEFINITIONS

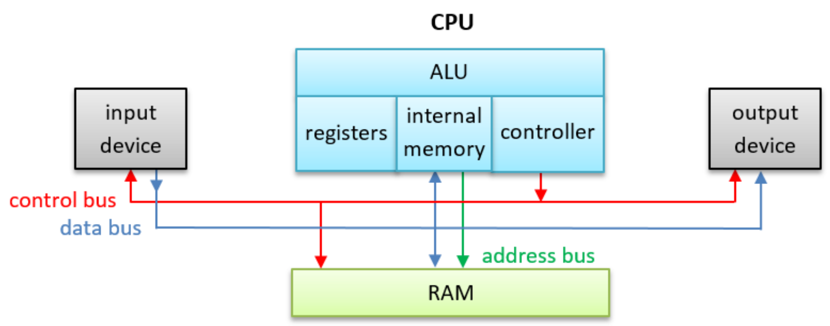
Controller: manages the execution of instructions
Arithmetic and Logic Unit (ALU): processes and manipulates data
Register: fast access temporary data store
Internal memory: fast access memory on the CPU

Other examples of registers include:

- Program Counter (PC) – a counter that keeps track of the memory address of which instruction is to be executed next.
- Memory Address Register (MAR) – the address in the main memory that is currently being read or written.
- Current Instruction Register (CIR) – a temporary holding area for the instruction that has just been fetched from memory.

Internal memory

Internal memory (sometimes called *level 1 cache memory*) is fast access temporary storage on the CPU. Data is moved from the registers to the internal memory when it is not being actively used. Data from internal memory can then either be written to RAM or called back into the registers for further processing.



Buses

Buses allow data to be transferred to different parts of the computer. There are three main buses used by the CPU.

1. Address bus. When data is saved or loaded from memory, the address at which it is to be stored or loaded from must be sent. The storage address of data always travels along an address bus.
2. Data bus. Data will then need to be moved between several parts of a computer. The path along which data travels is called a data bus.
3. Control bus. The controller uses the control bus to send control signals to different parts of the computer.

The fetch-decode-execute cycle

There are **three** steps to processing instructions given by a currently running program:

1. The fetch cycle takes the address required from memory, stores it in the current instruction register, and moves the program counter on one so that it points at the next instruction.
2. The control unit authenticates the instruction in the current instruction register. The instruction is decoded to determine the action that needs to be carried out.
3. The actual actions that happen during the execution cycle depend on the instruction itself.

CPU performance and specification

When we use a computer, we want the instructions to be carried out very fast. As the instructions become more complicated (for example, creating a 3D animation or editing a video file), we demand more from the CPU. The technological advances we have seen in processor technology have largely been driven by the need for speed.

CPU cache memory

Cache memory is a fast access type of memory; it's also very expensive. Because of the cost, most computer systems have very little cache memory, e.g. very few kB or MB compared to a Random Access Memory (RAM) where there is likely to be many GB. Cache memory improves the performance of the CPU as it is able to provide instructions and data to the CPU at a much faster rate than another system memory such as RAM. The more cache memory your system has, the better its performance is likely to be.

Clock speed

The speed at which a processor operates is called the clock speed. The faster the clock speed, the faster the computer is able to run the fetch-decode-execute cycle (FDE) and therefore process more instructions. The speed of the processor is measured in Hertz (Hz). One clock tick per second would be measured as 1 Hz. Therefore, a processor that operates at 1,000 clock ticks per second would be a 1,000 Hz processor, also known as a 1 kHz processor.

At this stage, it is a good time to introduce *prefix multipliers* for clock speeds:

Prefix	Symbol	Multiplier	Power of 10
Kilo	k	1,000	10^3
Mega	M	1,000,000	10^6
Giga	G	1,000,000,000	10^9

The first Terahertz chip was created by DARPA (an agency of the United States Department of Defense) in 2014.

A typical modern day home computer would have a 2.5 GHz processor. This means the clock speed of the processor runs at 2,500,000,000 Hz or clock ticks per second.

The clock speed inside the CPU can sometimes be changed. A processor can be set to run faster than its original design. By doing this however, it uses more energy and produces more heat. If this heat is not removed through cooling, the CPU can overheat, which will damage the CPU and shorten its lifespan. This is called *overclocking*.

Some computer systems, especially mobile devices, set the clock speed of the CPU lower than its original design. This results in less power consumption, less heat being produced and will therefore increase the battery life of the device. This is called *underclocking*.

INTERESTING FACT

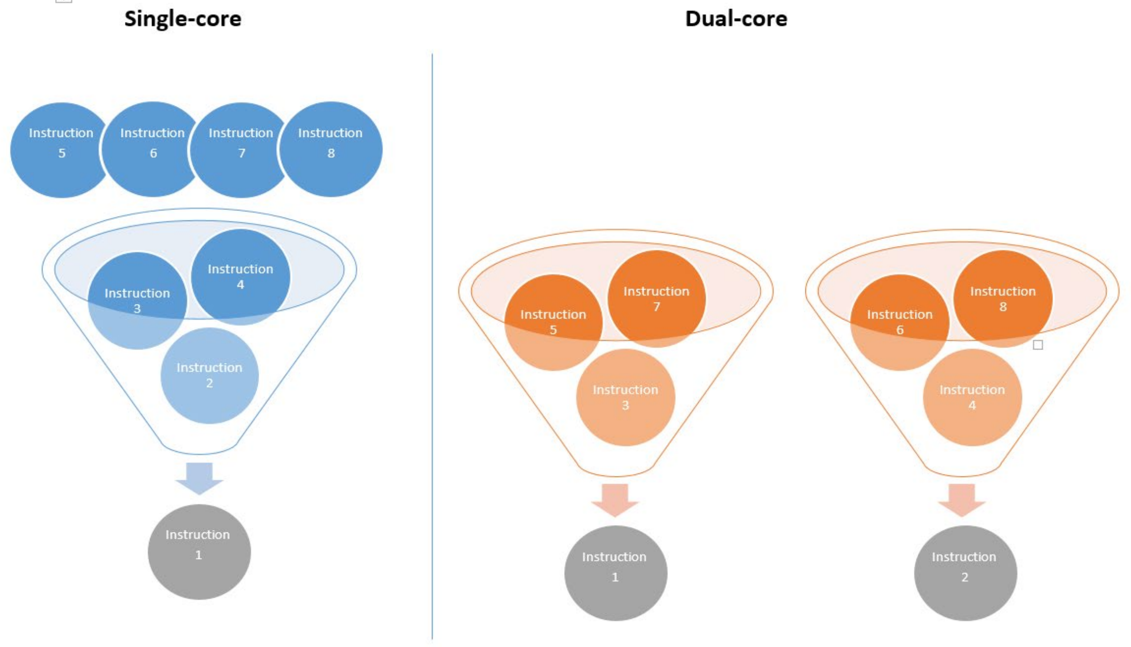
Most CPU chips are cooled using a fan mounted on a metal heat sink. Liquid cooling systems have been found to be more effective at cooling CPUs, although the water used in these systems conducts electricity and can therefore be dangerous. A computer designer, Seymour Cray, designed a computer cooling system that used artificial human blood to cool the CPU, as it does not conduct electricity.

Some devices are able to change their own clock speed dynamically. For example, when your computer is idle, the clock speed may be set at a lower rate than if you were running a CPU intensive program, such as a computer game.

Number of cores

We have assumed that each CPU has only one core. However, this isn't always the case, as some CPU chips have multiple cores. You may be familiar with the terms dual-core and quad-core. What exactly do they mean?

A core is the term used to describe the processing components within the CPU. Multi-core processors therefore have many processing components within the same CPU. Below is a diagram that illustrates a number of instructions waiting to be processed in single-core and dual-core CPUs.



In a single-core CPU, each instruction is processed one after the other, whereas in a dual-core CPU, two instructions may be processed at the same time. In theory, a dual-core CPU should be able to process instructions twice as fast as a single-core CPU. However, this isn't always the case, as sometimes *Instruction 2* may need the result of *Instruction 1* before it can be processed.

In general, a computer running many programs at the same time will run faster on a multi-core processor than on a single-core processor.

INTERESTING FACT
Many high-end gaming consoles include CPU chips with multiple cores. The Sony Playstation 4 and the Xbox One X both have an 8 core CPU.

RISC and CISC processors

There are two main types of processor, namely Reduced Instruction Set Computer (RISC) and Complex Instruction Set Computer (CISC).

RISC processors can process a limited number of relatively simple instructions. To carry out more complex commands, the problem is broken down into a longer list of simpler instructions. The advantage of this is that a RISC processor is able to process these simpler instructions quickly. Processing simpler instructions also requires less circuitry to decode and execute these instructions, which in turn means less power consumption and therefore less heat being generated.

CISC processors can process a large number of complex instructions. This allows the processor to understand and carry out complex tasks with only a few instructions. The advantage of this is that a CISC processor is able to process complex instructions, without having to break them down into many simpler instructions. Processing complex instructions however requires more circuitry to decode and execute these instructions, which in turn means more power consumption and therefore more heat being generated.

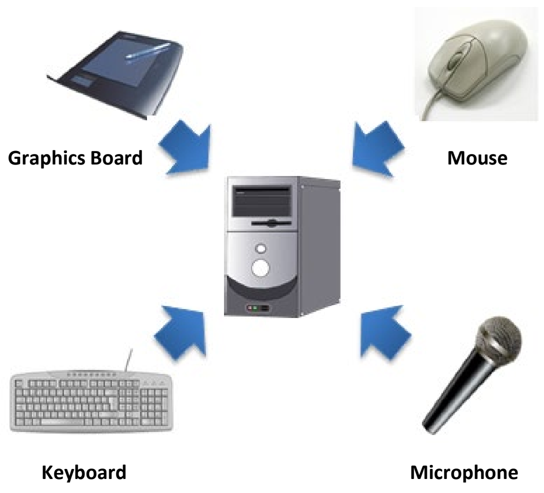
Input and Output

Input devices

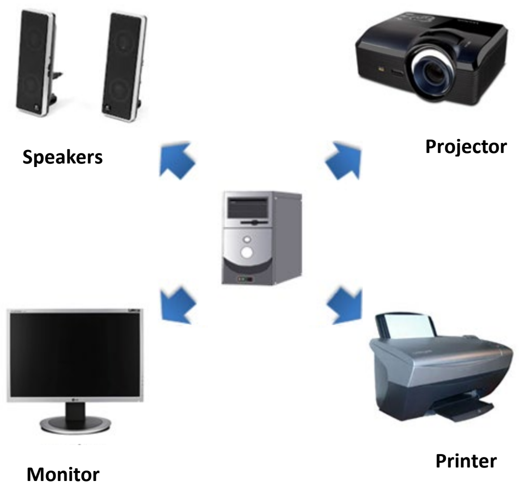
An input device allows data, such as text, images, video or sound, to be entered into a computer system.

Output devices

There are many outputs created by a computer system. These include printed documents, on-screen data and sound.



Common hardware input devices



Common hardware output devices

Input devices

Mouse

A mouse is an input device that allows the user to control the co-ordinates and movements of a cursor on the computer screen. The left button is used to select items and the right button is used to access menus (these can be changed around in settings). Most mice now use a laser to track location on a smooth surface and mice can be wired or wireless.

Trackball

A trackball is an input device similar to a mouse, that allows the user to locate the cursor. Unlike the mouse, however, the trackball remains stationary and the user moves the cursor by moving the ball around in the socket. Some users believe that the use of a trackball gives better control over the cursor, and therefore use a trackball for computer aided design (CAD).

Computer keyboard

Computer keyboards are used to input data and commands into the computer by pressing the keys. Computer keyboards are common in the workplace and are usually used together with a mouse.

Concept keyboard

Concept keyboards look like computer keyboards, but have an image on each key. The images on the keys are chosen to represent the command. For example, in a restaurant, a key may be used for a burger, a cheeseburger or a cheeseburger with bacon.

Microphone

A microphone is an input device that receives analogue sound waves and converts them into electrical signals understood by the computer. Microphones play an important role in speech recognition.

Digital camera

A digital camera is an input device that captures images (and sometimes videos) digitally. A digital camera uses an image sensor and a chip to capture an image, as opposed to the film used in traditional cameras.

2D scanner

2D scanners convert documents or 2D images into digital files. 2D scanners can be run with additional software such as an optical mark reader (OMR) or optical character recognition (OCR). One example would be using OCR software in the computer to read handwriting and convert it into digital text.

3D scanner

A 3D scanner is an input device that generates a 3D model of a scanned object. It may use x-ray, laser, light or sound waves to generate the object in 3D.

Interactive whiteboard

An interactive whiteboard is usually used in classrooms. This device was developed long before touch screens. It's cheaper than touch screens and differs from normal screens as it can be used in many different ways when used alongside a projector. It can be used for navigation systems or to write/design with your fingers or a stylus.

Touch screens

A touch screen is a digital visual display that also works as an input device that responds to the user's touch. It allows users to make selections by touching the screen.

Barcode scanner

A barcode is a code that can be read by a machine. The code is represented by a series of black and white lines. These lines represent numbers from 0 to 9. The use of barcode scanners speeds up the process of data input into a system, e.g. scanning items at a check out desk in a supermarket.

QR code scanner

QR code scanners as seen on smartphones can scan QR codes by taking a picture of them. The QR codes normally hold more data than barcodes, e.g. web addresses, contact details, calendar registrations and details of goods in factories and warehouses.

INTERESTING FACT

Doug Engelbart made the first computer mouse in 1964.
It was made out of wood!

Output devices

Monitor

A monitor is an electronic visual computer display. It includes a screen and the case in which all circuitry is enclosed. Most monitors used with devices such as laptops, PDAs and desktop PCs are made using LCD screens as they are lighter and more energy efficient.

Speaker

Speakers are used to produce audio output that can be heard by the listener. When they receive audio input from a device, the electromagnetic waves are converted into sound waves. This input may be in either analog or digital form. Analog speakers simply amplify the analog electromagnetic waves into sound waves. Digital speakers must first convert the digital input into an analog signal, then generate the sound waves.

Printer

A printer is an output device that prints paper documents. This includes text documents, images, or a combination of both. The two most common types of printers are inkjet and laser printers. Inkjet printers are commonly used by consumers, while laser printers are a typical choice for businesses.

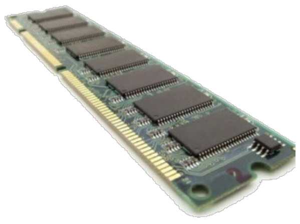
Projector

A projector is an output device that projects an image onto a large surface, such as a white screen or a wall. It may be used as an alternative to a monitor or a television when showing video or images to a large group of people.

Primary storage

Random Access Memory (RAM)

RAM is used for the temporary storage of currently running programs and data, e.g. the operating system, a text editor program. It consists of a large number of store locations, each of which is identified by a unique address. The data in each store location can be changed. RAM is volatile – data is lost when the power is switched off.



Example: When you are working on a word-processed document, the program you are using and the data within the document are both stored in RAM. The process is different when using a web-based word processing program as all letters and numbers pressed on the keyboard are sent immediately to the program over the internet.

Read Only Memory (ROM)

ROM is used for the permanent storage of data. The data in each store location cannot be changed. ROM is permanent – data is not lost when the power is switched off.

Example: ROM can be used for storing programs such as the BIOS. The disadvantage of using ROM to store the BIOS is that it cannot be upgraded. The program on your calculator is held on a ROM chip.

KEY INFORMATION

Basic Input/Output System (BIOS): A low-level program that handles input and output operations relating to the system's keyboard and screen. It provides an interface between the hardware and the operating system. One of its primary functions is loading and executing the *bootstrap loader* – the program that loads the operating system.

Flash memory

Flash memory is used for the permanent storage of data. However, the data stored in flash memory can be changed. Flash memory is permanent – data is not lost when the power is switched off.

Example: Flash memory can be used for storing the programs such as the BIOS, which is advantageous as the BIOS can then be upgraded.

RAM Cache memory

RAM Cache memory is used for the temporary storage of frequently accessed data and instructions. It consists of a small number of store locations that can be accessed very quickly by the CPU; it is quicker than RAM. Cache memory is volatile – this means that data is lost when the power is switched off.

Summary of different types of memory

	Permanent	Volatile	Data can be changed	Speed
Cache memory		✓	✓	★★★★
ROM	✓			★★★
RAM		✓	✓	★★
Flash memory	✓		✓	★

Secondary storage

Secondary storage is also known as backing storage.

INTERESTING FACT
The first commercial hard disk drives had the capacity to store approximately 5 MB and were the size of a dining room table.

Data from the memory is written in the secondary storage when the data is no longer being actively used, for retrieval at a later time.

The time a computer takes to access data stored on secondary storage is **longer** than the time it takes to access data from memory.

Data capacity

Data capacity is the amount of data a storage device can hold, measured in kilobytes (kB), Megabytes (MB), Gigabytes (GB) and Terabytes (TB). The most frequently used backing storage media are:

Media	Suitability	Typical capacity	Durability	Portability	Speed
Flash drive	Moving relatively small files from work to home	2 GB – 512 GB	★★★★	✓	★★★★
External hard drive	Backing up a home computer system	320 MB – 8 TB	★	✓	★★★
CD/DVD/Blu-ray disc	Storing multimedia files	650 MB (CD) 9 GB (DVD) 50 GB (Blu-ray)	★★★	✓	★★
Magnetic tape	Backing large commercial servers on multiple tapes	200 GB – 400 GB	★★	✓	★

Different types of data can create files that vary in size. In general, text based files are relatively small but audio and video files are much larger. Here are some typical file sizes.

File size	Typical contents
1 B	A single key stroke or a number from 0 to 255
70 B	One line of text
1 kB	A third of a page of text or a short email
8 kB	A school logo
30 kB	A basic web page
100 kB	Maximum size for all elements of a web page
500 kB	A five page word processed document or a PDF for downloading
1 MB	One minute of audio when stored as an MP3
700 MB	Maximum amount of data on one CD-ROM
5 GB	DVD movie
10 GB	HD movie
25 GB	Blu-ray movie
40 GB	4K movie

It's important to consider the type of data that is going to be stored when you are choosing a storage device.

Storage technologies

Optical

Optical storage media uses technology such as lasers. Laser beams are projected onto a CD/DVD or Blu-ray disc and if light is reflected back, then data is read as a 1. If light is not reflected back, data is read as a 0. Lasers are used to read and write information on a disk.

KEY INFORMATION

Binary digIT (BIT): in computer systems, data is represented by either a 1 or a 0.

Magnetic

This technology is used in hard disks and tapes. Data is stored on a magnetic medium, which can be a disc or a tape, by writing data using a write-head. Data can then be read by the read-head.

Solid state

Solid state technology is used in storage media such as flash memory sticks. The technology is called solid state as it doesn't have any moving parts, such as a read-head in magnetic storage. Solid state storage technology is increasingly used to replace both magnetic and optical storage, especially in mobile devices, where its low power consumption and high speed access is advantageous.

Storage requirements

Computer systems can only store and process binary digits, also known as BITs. A BIT is either a 1 or a 0. When 8 bits are stored as a binary number, they are collectively called a byte.

	Symbol	Value
Bit		1 bit
Nybble		4 bits
Byte	B	8 bits
kilobyte	kB	1024 bytes
Megabyte	MB	1024 kB
Gigabyte	GB	1024 MB
Terabyte	TB	1024 GB
Petabyte	PB	1024 TB
Exabyte	EB	1024 PB
Zettabyte	ZB	1024 EB
Yottabyte	YB	1024 ZB

INTERESTING FACT

Half a byte (4 bits) is called a nybble.

Additional hardware components

Motherboard

The motherboard is the main circuit board of a computer. The CPU and ROM will be mounted on the motherboard, which also provides RAM expansion slots, USB ports, PCI slots for expansion cards and controllers for devices such as the hard drive, DVD drive, keyboard and mouse.

Graphics Processing Unit (GPU)

A GPU is a microprocessor that performs the calculations needed to produce graphic images on screen. The CPU performed these calculations initially, but as more complex applications were developed, such as 3D graphics and video quality animations, the GPU was introduced to offload those tasks from the CPU.

GPUs can be integrated within the circuitry of the motherboard, or provided on a dedicated graphics card.

Integrated GPU

An integrated GPU uses the computer’s RAM. An integrated unit is cheaper than installing a dedicated GPU. It generates less heat and uses less power. They are perfect for general graphics processing such as watching or editing videos and word processing.

Dedicated GPU

A dedicated GPU has its own video memory. Dedicated cards provide the best visual experience. They are used by people such as graphic designers and people who play a lot of games, but they use more power and need a good cooling system. GPUs are also used to mine digital currency due to their processing ability.

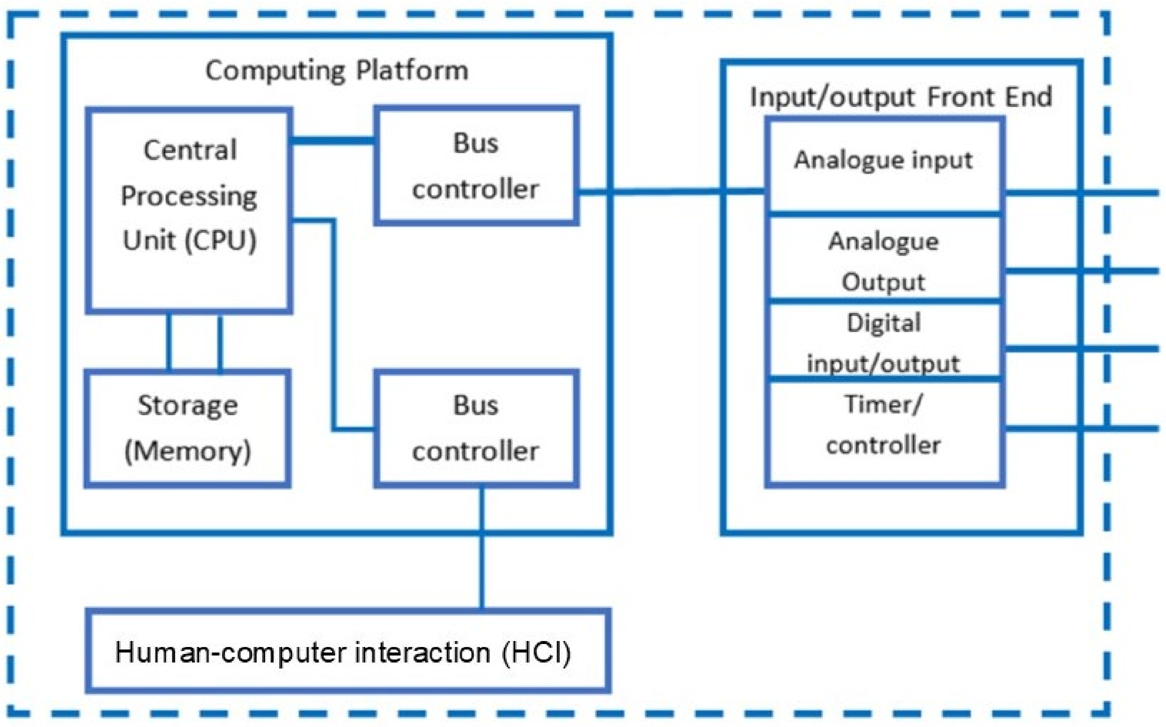
Sound cards

Sound cards may be on the motherboard or designed to fit a PCI slot. They enable the computer to output sound through speakers, record sound from a microphone and manipulate sound stored on a disk. Sound cards convert analogue input signals into digital data and reverse this process for audio output.

Embedded systems

An embedded system is a combination of software and hardware that performs a specific task rather than a general-purpose computer that is designed to carry out multiple tasks.

Embedded systems are included as a part of a complete device often with hardware and mechanical parts. As the systems carry out specific tasks they can be designed to be small and have a low cost. Mass-production of embedded systems can save large amounts of money.



The software written for an embedded system is called firmware. The instructions are stored in read-only memory or in Flash memory. The software runs with limited computer hardware resources, little memory and no peripherals.

Most embedded systems are reactive – they react to conditions such as temperature, weight, vibration and air quality. These systems detect external conditions and react to them by recording data, turning motors on or off, sounding an alarm or sending a message to another processor.

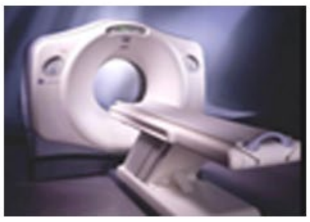
Reactive embedded systems often control real time events so must be completely reliable. For example, drivers rely of the anti-lock braking system of their car working correctly to avoid accidents on the road.

When an embedded system performs operations at high speed, and if it is very reliable, it can be used for real-time applications. If the size of the embedded system is very small and power consumption is very low, the system can be easily adapted for different situations.

INTERESTING FACT
98% of the microprocessors manufactured are installed in embedded systems.

Some examples of devices that incorporate embedded systems are:

Electronics	Mobile phones, games consoles, printers, televisions, digital cameras.
In the home	Washing machines, microwave ovens, refrigerators, dishwashers, air conditioners.
Medical equipment	CT scanners, electrocardiograms (ECG), MRI scanners, blood pressure monitors, heartbeat monitors.
Cars	Electronic fuel injection systems, anti-lock braking systems, air-conditioner controls.



2. Logical Operations

Using logical operators: NOT, AND, OR, and XOR

Computers are binary devices that use 1 and 0 to represent data. Boolean algebra involves looking at statements that will, when evaluated, result in a true or false value. Propositional logic means that a statement or proposition defined in terms of true or false follows mathematical rules that allow the proposition to be manipulated.

This in turn allows the simplification or derivation of logic statements. In this section, you will learn about propositional logic and some of the tools that can define real world problems as propositional statements. You will also learn about some of the key tools that can be used to derive and simplify these logic statements.

Propositional logic

Proposition A is 'It's raining'
Proposition B is 'I have an umbrella'
Proposition C is 'I will get wet'

Logic propositions such as 'it's raining' can have a value of true or false. Statements such as 'what is the weather?', that can generate a number of different answers, cannot be considered logic propositions. A proposition is an atomic value or placeholder and is represented algebraically by assigning letters to each proposition. In the above statements, A was used to represent the proposition 'it's raining'. B and C were also used to represent two different statements. Most rules used to simplify logic are not dependent on the meaning of the propositions, but focus on how a logic statement is structured. When defining problems, it's useful to give the propositions meaning in order to provide more context. Additional programming focus can also be given by assigning conditional expressions to them.

Propositional logic uses a number of symbols to represent logical links. These links are summarised in the table below. A logic statement includes a combination of propositions connected by logical links. To make it simpler, informal terms have been given to each symbol, along with their formal names, as shown in the table below.

Symbol	Formal term	Informal term
.	Connection	AND
+	Separation	OR
$\bar{A}$	Negation	NOT
$\oplus$	Exclusive separation	XOR

Different symbols are used for Boolean algebra and it's important that you are familiar with these.

Symbol	Alternative symbol
.	$\wedge$
+	$\vee$
$\bar{A}$	¬A
$\oplus$	$\veebar$

Connection (AND)

Consider this connected expression: 'It's raining and I have an umbrella'. The key word is 'and'. For this statement to be true, both propositions represented by A and B must be true. If one is false, the entire expression becomes false. A connection can be represented by the simple truth table below.

* Please note: these tables use 1 and 0 to represent True (1) and False (0). This is what will be used in the examination.

A	B	A AND B
1	1	1
1	0	0
0	1	0
0	0	0

When we use a connection to connect two propositions, it is represented by the full stop symbol. If A represents 'It's raining' and B represents 'I have an umbrella', we can represent the connection of these two propositions as the statement: A . B

Separation (OR)

Sometimes, we want to see if one thing or another is true. The truth table below shows two propositions connected using a separation.

A	B	A OR B
1	1	1
1	0	1
0	1	1
0	0	0

Separation is represented by the symbol + and therefore to show the separation of two propositions we write: A + B

Negation (NOT)

In order to negate a proposition, for example 'It's not raining', we can use the negation operation, ¯ , which is also called NOT. Negation is a unary operator and operates on the proposition below it (or after it, if we use ¬). Therefore, if A represents 'It's raining', we can represent the negative by putting a bar over statement A to give: $\overline{\square}$

A	NOT A
1	0
0	1

Exclusive separation (XOR)

Sometimes we want to see if only one thing or the other is true. The truth table below shows two propositions connected by an exclusive separation.

A	B	A XOR B
1	1	0
1	0	1
0	1	1
0	0	0

Exclusive separation is represented by the symbol $\oplus$ and to represent the exclusive separation of two propositions we write: $A \oplus B$

Introduction to Boolean Algebra

Here:
True will be represented by 1.
False will be represented by 0.

A variable will ususally be represented by a single letter.

The logical operator OR is represented by the character '+'.
For example, A + B means A OR B.

The logical operator AND is represented by the character ' . '.
For example, A . B means A AND B.

$A.\overline{B} + \bar{A}.B$ is an equation for A XOR B. The XOR operator can also be represented by the symbol $\oplus$. For example: A $\oplus$ B means A XOR B. In order to understand how the formula $A.\overline{B} + \bar{A}.B$ works, consider the statement, '*one or the other but never both*'.

The logical operator NOT is represented by an overbar. For example: $\bar{A}$ means NOT A.

OR

The OR operator takes two inputs and returns a true value (1) if either of the inputs are true (1).

0 + 0 = 0	0 + 1 = 1
1 + 0 = 1	1 + 1 = 1

AND

The AND operator takes two inputs and returns a true value (1) if both inputs are true (1).

0 . 0 = 0	0 . 1 = 0
1 . 0 = 0	1 . 1 = 1

NOT

The NOT operator takes one input (this is a unary operator) and returns the opposite of that input.

$$\overline{0} = 1$$
$$\overline{1} = 0$$

XOR

XOR takes two inputs and only returns a true value (1) if exactly one input is true (1).

$0 \oplus 0 = 0$	$0 \oplus 1 = 1$
$1 \oplus 0 = 1$	$1 \oplus 1 = 0$

Order of precedence

In algebraic expressions, there is an order of precedence for the operations. The mnemonic BIDMAS can help us remember this order – Brackets, Indices, Division/Multiplication/Addition/Subtraction.

Similarly, there is an order of precedence for the operations used in Boolean algebra. The order of precedence is shown below (highest precedence first):

Brackets
NOT
XOR
AND
OR

It's important to remember that AND takes precedence over OR. Therefore, the expression A.B + C will correspond to the truth table:

A	B	C	A.B	A.B + C
0	0	0	0	0
0	0	1	0	1
0	1	0	0	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	1
1	1	1	1	1

So, A.B + C means exactly the same as (A.B) + C, but the brackets have been removed. They aren't needed as AND takes precedence over OR.

The OR operator will be placed in brackets if OR needs to be operated first. The expression would then be A.(B+C). The truth table would look like the following:

A	B	C	B+C	A.(B + C)
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

We can see from these truth tables that the order of operation of the operators has a substantial effect on the result. Brackets are needed in order for OR to take precedence over AND.

Commutative Laws

These laws state that the order of (certain) operands doesn't matter. You will also be very familiar with these laws from algebraic expressions in mathematics – they're so obvious that you never think of them at all, e.g. 3 x 5 is the same as 5 x 3.
The commutative laws of Boolean algebra are:

$A.B = B.A$
$A+B = B+A$
$A \oplus B = B \oplus A$

Associative Laws

These laws state that when all operators are of the same type, it doesn't matter in what order they're operated (for certain operators). These laws are also used in algebraic expressions and are so obvious that you may have never thought of them, e.g.
(3 x 5) x 4 = 3 x (5 x 4).

The associative laws of Boolean algebra are:

$A.(B.C) = (A.B).C$
$A +(B+C) = (A+B) + C$
$A \oplus (B \oplus C) = (A \oplus B) \oplus C$

Simplifying Boolean expressions (part 1)

Simplifying an expression means writing the expression in a way that uses fewer logical operators, but has the same meaning.

Basic Rule 1 – Identity Law:
Using the OR operator with an expression that has a FALSE value (0).

A+0 = A

Test with a truth table:

A	0	A+0
0	0	0
1	0	1

In every row in column A+0, we can see that A+0 is always equivalent to the corresponding row in column A, and therefore the expressions are equivalent.

This means that every time we use OR with an expression that has a False value (0), it will simplify to the expression only.

Basic Rule 2 – Annulment Law:
Using the OR operator with an expression that has a TRUE value (1).

A+1 = 1

Test with a truth table:

A	1	A+1
0	1	1
1	1	1

We can see that every row in column A+1 contains 1, so when we use OR with any expression that has a True value (1), this can always be simplified to True (1).

Basic Rule 3 – Idempotent Law:
Using the OR operator with an expression and another copy of that expression.

A+A = A

Test with a truth table (note that this is also true for $\overline{A} + \overline{A} = \overline{A}$):

A	A	A+A
0	0	0
1	1	1

We can see that every row in column A+A is always the same as the corresponding row in column(s) A, so A+A is an equivalent expression to A. When the OR operator is used with the same expression twice, that expression can be simplified to only one of those expressions.

Basic Rule 4 – Inverse Law:
Using the OR operator with an expression that has an inverse value.

$A+\overline{A} = 1$

Test with a truth table:

A	$\overline{A}$	$A+\overline{A}$
0	1	1
1	0	1

We can see that every row in column $A+\overline{A}$ contains 1, so when we use OR with any expression that has an inverse value, this can always be simplified to True (1).

Basic Rule 5 – Annulment Law:
Using the AND operator with an expression that has a False value (0).

A.0 = 0

Test with a truth table:

A	0	A.0
0	0	0
1	0	0

We can see that every row in column A.0 is always 0 (False), so when AND is used between an expression that has a 0 value, it will always be simplified to False (0).

Basic Rule 6 – Identity Law:
Using the AND operator with an expression that has a True value (1).

A.1 = A

Test with a truth table:

A	1	A.1
0	1	0
1	1	1

We can see that every row in column A.1 is always the same as the corresponding row in column A. Therefore, the expressions are equivalent.

Basic Rule 7 – Idempotent Law:
Using the AND operator with an expression and another copy of the same expression.

A.A = A

Test with a truth table:

A	A	A.A
0	0	0
1	1	1

We can see that every row in column A.A is always the same as the corresponding row in column(s) A, so A.A is equivalent to A. When the AND operator is used with the same expression twice, that expression can be simplified to only one of those expressions.

Basic Rule 8 – Complement Law:
Using the AND operator with an expression that has an inverse value.

A.$\bar{A}$ = 0

Test with a truth table:

A	$\bar{A}$	A.$\bar{A}$
0	1	0
1	0	0

We can see that every row in column A.$\bar{A}$ contains 0, so when we use AND with any expression that has an inverse value, this can always be simplified to False (0).

Basic Rule 9 – Double Complement Law:
Using the NOT operator twice with one expression.

$\overline{\overline{A}}$ = A

Test with a truth table:

A	$\overline{A}$	$\overline{\overline{A}}$
0	1	0
1	0	1

We can see that every row in column $\overline{\overline{A}}$ is always the same as the corresponding row in column A, therefore the expressions are equivalent. If NOT is used twice with one expression, it simplifies to just the expression.

Basic Rule 10 – Absorptive Law:
Enabling a reduction in a complicated expression to a simpler one by absorbing like terms.

A + (A.B) = A

Test with a truth table:

A	B	A.B	A+A.B
0	0	0	0
0	1	0	0
1	0	0	1
1	1	1	1

We can see that every row in column A + A.B is always the same as the corresponding row in column A, so we can see that the expressions are equivalent.

Basic Rule 11 – Absortive Law:
Enabling a reduction in a complicated expression to a simpler one by absorbing like terms.

A.(A+B) = A

Test with a truth table:

Remember, as the OR is in brackets, A+B takes precedence, so we solve this first in the truth table.

A	B	A+B	A.(A+B)
0	0	0	0
0	1	1	0
1	0	1	1
1	1	1	1

We can see that every row in column A.(A+B) is always the same as the corresponding row in column A, so we can see the expressions are equivalent.

Alternative test for Basic Rule 11 (this will use information from later on in the notes)
A.(A+B)
= A.A + A.B (Expand the brackets – more details later on in the notes)
= A + A.B (Use Basic Rule 7)
= A (Use Basic Rule 10)

IMPORTANT: Basic Rules 10 and 11 also work in reverse, e.g. the following is true for Basic Rule 11: $\overline{A}+(\overline{A}\,.\,\overline{B}) \equiv \overline{A}$

Simplifying Boolean expressions (part 2)

Expansion of brackets – Distributive Law:

You will be familiar with the expansion of brackets in algebraic expressions, e.g. 3(y+9) = 3y + 27. It's also possible to expand brackets in Boolean algebra when an expression is AND-ed with an expression enclosed in brackets. This can often help simplify the expression (although sometimes it doesn't help and it's best not to expand the brackets).

Example:

$$X.(Y + Z)$$

This is the expression, X, being AND-ed...

...with the expression, Y+Z in brackets.

$$X.(Y + Z) = X.Y + X.Z$$

To expand the brackets, the expressions outside the brackets are AND-ed with each term in the expression inside the brackets.

Factorising

This is the opposite to expanding brackets. You will be familiar with factorising in algebraic expressions – brackets are added to an expression and the common factor is placed outside the brackets, e.g. 4y+8 = 4(y+2). It is also possible to factorise more than one Boolean algebra expression. Doing so can sometimes simplify an expression.

Example:

$$X.Z + X.Y$$

The same term (X) appears in the expression on both sides of the operator '+' so this expression can be factorised.

$$X.Z + X.Y = X.(Z + Y)$$

Therefore this expression...

...can be factorised as in the above expression.

3. Communication

Networks

A network consists of a number of computer systems connected together. There are many advantages and disadvantages of using a computer network over a stand-alone computer.

Advantages	Disadvantages
• Share hardware • Share software • Share data/files • Easier for internal communication/can send email • Central backup • Easier to monitor network activity • Centrally controlled security • Can access data from any computer	• A network manager may need to be employed – expensive • Security problems – files sent between computers could spread a virus • Hackers can gain access to data more easily • If the server is down, all workstations on the network are affected • Initial cost of servers, communication devices etc. can be expensive

There are two main types of network, namely a **Local Area Network (LAN)** and a **Wide Area Network (WAN)**.

A LAN is a network in which the computer systems are all located relatively close to each other, for example in the same building or on the same site, such as a school.

A WAN is a network in which the computer systems are all located relatively far from each other, for example in different buildings all over the country or in different countries. The internet is an example of a WAN. Note that many LANs could be linked using a WAN.

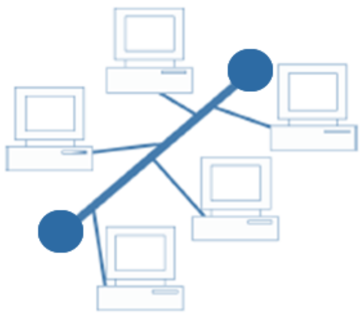
Computer networks use agreed upon protocols to communicate, i.e. common methods of sending data and consistent data formats. If they did not agree on the protocols to be used, the individual computer systems would not be able to communicate with each other.

Network topologies

A network topology is the theoretical layout of computer systems on a network. There are a number of different network topologies. Common network topologies include:

- bus network
- ring network
- star network
- mesh network.

Bus network

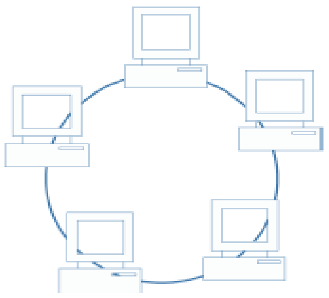


The computer systems, also called the *nodes* of the network, are all connected to a single cable on which data can be sent, called the bus. A bus network has terminators on each end, which are needed to ensure the network functions correctly.

The bus carries data packets along the cable. As the packets arrive at each computer system, it authenticates the destination address contained in the packet to see if it matches its own address. If the address doesn't match, the computer system ignores the packet. If the address of the computer system matches the address contained in the packet, it processes the data.

Advantages	Disadvantages
• Easy to implement and add more computer systems to the network • Quick to set up – well suited for temporary networks • Cost-effective – less cabling	• It is difficult to troubleshoot the bus • Limited cable length and limited number of stations – performance degrades as additional computers are added • If there is a problem with the main cable or connection, the entire network goes down • Low security – all computers on the bus can see all data transmissions • Proper termination is required • Data collisions are more likely, which causes the network to slow down. A collision is when two computers try to send a data packet at the same time

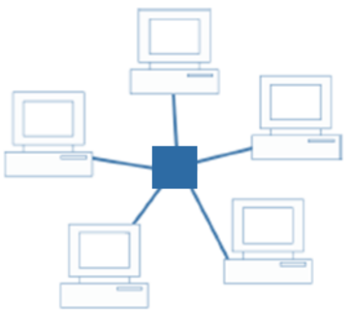
Ring network



In a ring network, computer systems are connected in a ring or a loop. Data packets are sent around the ring, being passed from one computer system to the next until they arrive at their destination.

Advantages	Disadvantages
• Data is quickly transferred without a bottleneck – consistent data transfer speeds • The transmission of data is relatively simple as data packets travel in one direction only • Adding additional nodes has very little impact on bandwidth • It prevents network collisions	• If any of the computer systems fail, the ring is broken and data cannot be transmitted efficiently • If there is a problem with the main cable or connection, the entire network goes down • It is difficult to troubleshoot the ring • Because all nodes are wired together, to add a another you must temporarily shut down the network

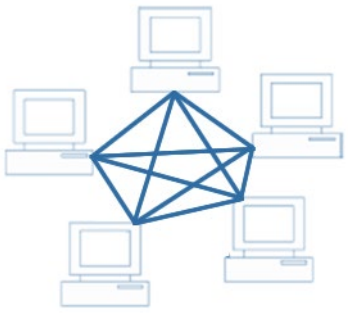
Star network



In a star network, each computer system is connected to a central node, also known as a hub.

Advantages	Disadvantages
• Good performance/fast network speed • Easy to set up • Possible to add more computer systems without taking the network down • Any non-centralised failure will have very little effect on the network • Minimal network collisions • Better security	• Expensive to install – more cabling required • Extra hardware required, such as a hub

Mesh network



In a mesh network, each computer system is directly connected to as many other computer systems as possible. The image above shows a full mesh network, where all computer systems are connected to each other. It is also possible to have a partial mesh network, where only some of the computer systems are connected in similar fashion to a mesh topology, while the rest are only connected to one or two devices. This is called a partial mesh network. The mesh topology is the most common network topology used on wireless networks.

Advantages	Disadvantages
• Data can be transmitted from different nodes simultaneously • Mesh topologies can withstand high traffic • Each connection can carry its own data load • If one node fails, there is always an alternative present, so data transfer isn't affected • A fault can be diagnosed easily • Expansion and modification in topology can be done without disrupting other nodes • Provides high levels of security and privacy	• Installation and configuration can be difficult as the network grows • Cabling costs are high • There is a high chance that many of the network connections will be redundant • Set-up and maintenance of mesh topologies is very difficult • Administration of the network is difficult

Connectivity

To connect a computer system to a network, a Network Interface Card (NIC) is required. A physical hardware port allowing a cable to connect your computer system to the network provides one method of connection. The second method is to connect a computer system using a wireless connection, called Wi-Fi.

Typical network speeds

A physical connection may be made using:

- a copper cable, with typical data transfer speeds of between 100 Megabits per second (Mb) and 1 Gigabit per second (Gb)
- a fibre-optic connection which has typical data transfer speeds of between 1 and 10 Gb

Wi-Fi connections have typical data transfer speeds of 54–108 Mb but can go much higher. However, this can be severely affected by the distance between the device providing the Wi-Fi connection and the computer system. The data transfer speed can also be severely affected by atmospheric conditions, such as the weather, and building infrastructure.

Circuit switching

Circuit switching is a type of networking technology that provides a temporary but dedicated link between two stations or nodes, regardless of the number of switching devices through which the data has to travel. During the connection, no other data can be transmitted along the same route. The landline telephone system is an example of a circuit switched network. When you phone someone and they answer, a circuit connection is made and you can pass data along the connection until you put down the telephone to end the connection.

The main advantage of circuit switching is that it is reliable. Once the connection is established, it is fast and generally error free. However, it takes time to establish the connection. Should anywhere on the route fail, the connection will be broken.

To overcome the problems with circuit switching, packet switching was developed. Rather than relying on a dedicated connection, packet switching breaks the data down into small packets that can be sent by more than one route.

Packet switching (including data redundancy)

Packet switching is the process of delivering packets from one computer system to another using a designated device, such as a *switch* or a *router*. Packets are provided to a network for delivery to a specified destination. Each data packet is redirected by a computer system along the network, until it arrives at its destination. Data may be split up into a number of packets. These packets are transmitted over a network and may take different routes to its destination. When all the packets have arrived, the data is reassembled. The internet is an example of a packet-switching network.

Packets

A **packet** is a collection of data that is transmitted over a **packet-switching network**.

Here is a simplified diagram showing what a packet will typically contain:

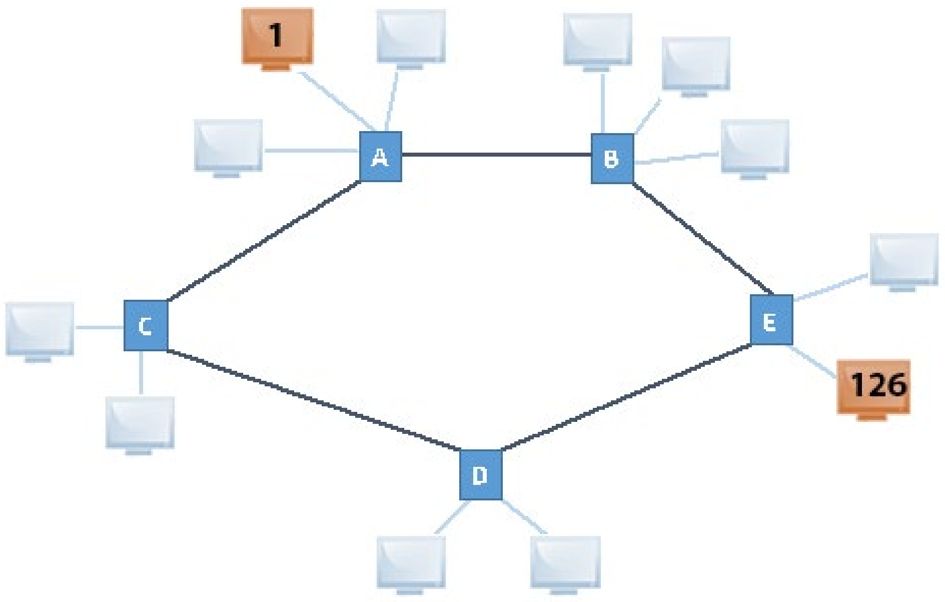
The source address	The destination address
Information which enables the data to be reassembled into its original form	
Other tracking information	
The data itself	A checksum that authenticates the data, i.e. checks it hasn't been corrupted

INTERESTING FACT

When packets are transmitted over a Wi-Fi network, they can be intercepted by any device; this is called *packet sniffing*. If you perform thorough analysis on a large number of packets, you can often break the encryption. This is why security services, such as the National Security Agency, do not allow any Wi-Fi devices on their network.

Routing

Routing is the name given to the method of selecting paths along which packets are sent on a computer network. Specialist computer systems such as routers, switches, bridges, firewalls and ports construct a *routing table* in their memory. This stores a number of routes which are the best to use to send packets to reach a specific destination. Maintaining accurate routing tables is essential for ensuring that packets are delivered as quickly as possible.



In the example shown above, computer system 1 is sending a packet to computer system 126. Clearly, the quickest route for the packet to arrive at its destination is to be sent from router A, on to router B, followed by router E for delivery to computer system 126. This path would be determined by routing, using a routing table. A poorly constructed routing table may choose to send the packet from router A, on to router C, followed by router D and then router E for delivery to computer system 126. This would take longer and is not a good use of network resources. But A>C>D>E may be faster, depending entirely on the cost (hop count) of the routes.

Most routers use only one network path at a time, such as the preferred route above (Computer system 1 > Router A > Router B > Router E > Computer system 126). Some multipath routing techniques enable the same packets to be sent using multiple alternative paths at the same time. This means that in the event of Router B failing in the transmission above, the same packet would also have been sent via the alternative longer route set out above (Computer system 1 > Router A > Router C > Router D > Router E > Computer system 126), to ensure the packet arrives at its destination.

IP addresses

An IP address is an address which is allocated to a computer system on a network, usually by a DHCP (Dynamic Host Configuration Protocol) server. Alternatively, you may assign your own IP address if you do not wish to rely on the services of a DHCP server. An example of an IP address is 195.10.213.120.

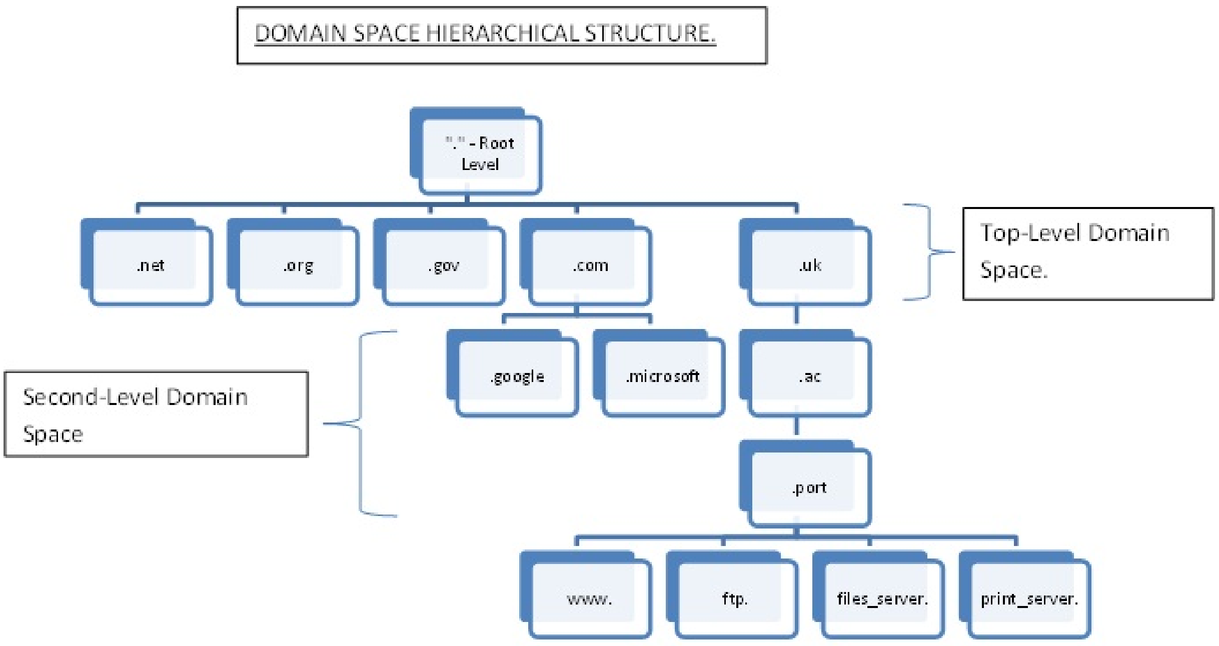
It is used to uniquely identify computer systems on a network, thus allowing communication between them. In routing tables, the corresponding IP address of a unique MAC address is stored and updated as necessary.

Internet Domain Name System (DNS)

A Domain Name System (DNS) is a distributed database that matches IP addresses to computer system resources.

One example of this is to match an IP address to a human friendly domain name. For example, if you wanted to visit the Google search engine, the computer system on which the website is stored has an IP address assigned to it; 172.217.31.164. Try typing this into the address bar of your web browser. You should be able to view the website that you would be more familiar with when accessing the domain name www.google.co.uk. Here, your computer system sent a request to its DNS server for the IP address that is mapped to the domain name www.google.co.uk. The DNS server returned the IP address 172.217.31.164, which allowed your computer system to communicate with the computer system where the Google search engine is stored.

Of course there are many different DNS servers located world-wide. If your local DNS server does not store the address of the resource you are requesting, it will pass the request along to another higher level DNS server, such as the DNS server of your Internet Server Provider (ISP). If again the address is not found, your ISP's DNS server will pass the request on to a higher level DNS server which may be the DNS server responsible for an entire zone, such as the *.co.uk* zone. This continues until the address is found (and returned to the local server) or the DNS query fails.



Another example where a DNS server is used is where a computer system, on joining a network, would query the DNS server for the IP address of other useful computer systems, such as the logon server, which stores the details of all usernames and passwords.

INTERESTING FACT

In 2015, YouTube users uploaded 400 hours of video per minute. That means that the equivalent of a 1000 days of video were uploaded every hour of every day.

Protocols

A **protocol** is an agreed format, which allows two devices to communicate. Put simply, a protocol is a set of rules. These rules can include the following:

- handshaking, where two devices establish their readiness to communicate
- how the sending device will indicate that it has finished sending a message
- how the receiving device will indicate that it has received a message
- the type of error checking to be used
- agreement on the data compression method to be used.

There are many standard protocols used with computer systems. The table below illustrates the protocols with which you need to be familiar:

Protocol	Description
TCP/IP (Transmission Control Protocol/Internet Protocol)	Two protocols that combine to allow communication between computer systems on a network. IP is a protocol that sets out the format of packets and an addressing system. TCP is a protocol that allows packets to be sent and received between computer systems.
HTTP (Hypertext Transfer Protocol)	HTTP is a protocol than can be used to transfer multimedia web pages over the internet.
FTP (File Transfer Protocol)	FTP is a protocol that can be used when copying a file from one location to another via a network or the internet. It is typically used for the transfer of large files, as it allows broken communications to resume transferring a file rather than having to restart.

A **protocol stack** is a set of protocols that work together to provide networking capabilities. It is called a stack because it is designed as a hierarchy of layers, each supporting the one above it and using those below it. The use of a layered approach enables different protocols to be substituted for each other, e.g. to allow for new protocols and different network architectures. The number of layers varies according to the particular protocol stack. However, the lowest layer will deal with physical interaction of the hardware, with each higher layer adding additional features, and user applications interacting with the top layer.

INTERESTING FACT

Although the Bluetooth protocol has been agreed, the protocol stack varies considerably from device to device. Try sending a photograph via Bluetooth from one smartphone to another.

TCP/IP 5 layer protocol stack model

TCP stands for Transmission Control Protocol and IP stands for Internet Protocol. There are five layers to this model:

- Physical layer
- Data link layer
- Network layer
- Transport layer
- Application layer.

Physical layer

The physical layer transmits the raw data. It consists of hardware such as switches. This layer deals with all aspects of setting up and maintaining a link between the communicating computers.

Data link layer

The data link layer sends data from the network layer to the physical layer. It divides the data to be sent into data frames. A data frame consists of a link layer header followed by a packet. This layer handles the acknowledgements sent from the receiver and ensures that incoming data has been received correctly by analysing bit patterns in the frames.

Network layer

The network layer is responsible for the addressing and routing of data. Routers belong to the network layer as they use logical addresses to direct the data from the sender to the receiver. A router determines the path the data should take based on network conditions. Routers manage traffic problems on the network such as the routing of packets to minimise congestion of data.

Transport layer

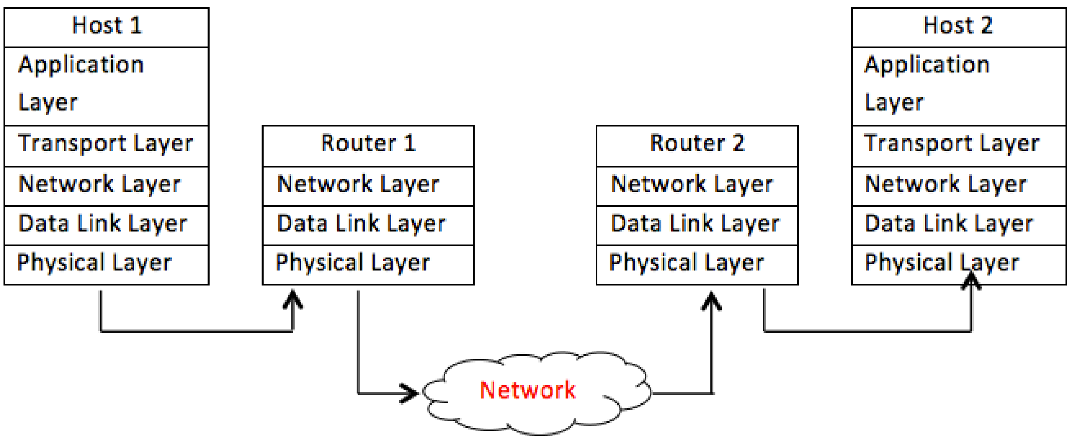
The transport layer ensures that data is transferred form one point to another reliably and without errors. The transport layer is responsible for making sure data is sent and received in the correct order. The transport layer is implemented in the sending and receiving computers, but not in the routers on the path between them. It acts as an interface between the communicating computers and the network.

Application layer

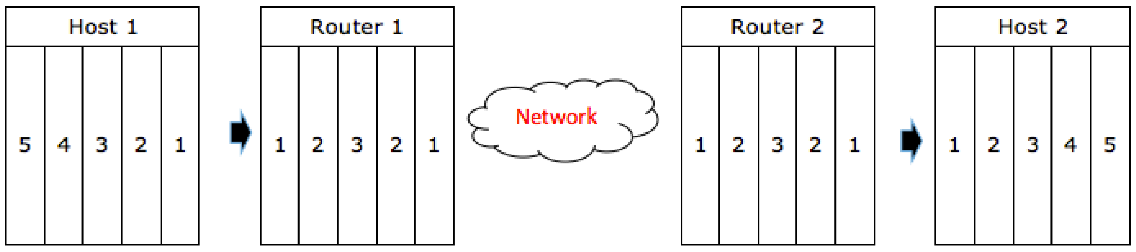
The application layer provides interfaces to the software to allow it to use the network. Examples of software include email, file transfer protocol (FTP) and the World Wide Web (WWW).

Sending data from Host 1 to Host 2

The diagram below shows Host 1 sending a message to Host 2. From Host 1, the data flows down through the 5 layers of protocols and then to Router 1. Router 1 is the gateway to the operating area of Host 1 and therefore only the network, data link and physical layers are involved. Similarly, with Router 2 only the three layers are involved as the data is passed into the operating region of Host 2. Finally, the data passes up through the layers to Host 2.



Data flow through **layers**



Layers and protocols

Layer	Protocol
Application layer	Hypertext Transfer Protocol (HTTP) Simple Mail Transfer Protocol (SMTP) File Transfer Protocol (FTP)
Transport layer	Transmission Control Protocol (TCP)
Network layer	Internet Protocol (IP)
Data link layer	Ethernet Protocol
Physical layer	Physical connection using a NIC to connect to the internet

Ethernet Protocol

At the data link layer, Ethernet Protocols describe how network devices can format data for transmission using frames and packets. Ethernet protocols are also used to define standards for types of network cabling used at the physical layer, and the corresponding transmission speeds.

Wi-Fi Protocol

Wi-Fi is a term used for certain types of wireless networks that use 802.11 wireless protocols for transmitting data using electromagnetic waves in place of cables. 802.11 wireless networks use security protocols, such as Wi-Fi Protected Access (WPA), to provide a level of security and privacy similar to that found on a wired network. Bluetooth is another example of a Wi-Fi protocol and WAPs (Wireless Application Protocols) are protocols to standardise the way wireless devices can be used for internet access.

Email Protocols

To use email, you must have an email client on your computer that has access to a mail server. Your Internet Service Provider (ISP) will often provide this server. The mail client and the mail server exchange information with each other using email protocols to transmit information.

1. **IMAP Protocol**
   IMAP is an email protocol that stores email messages on a mail server. It stands for Internet Messaging Access Protocol. It allows the email user to read and handle email messages as though they were stored locally on their own computer. The user can manage their email with facilities such as the ability to create folders to organise their messages, store draft messages in the server and delete unwanted messages.

2. **POP3**
   Post Office Protocol 3 (POP3) is the third version of a protocol for receiving email. POP3 receives email for a client and stores it in a single file on the mail server. When the email client logs onto the mail server, the email is transfered to the user's computer. There are no copies of the email stored permanently on the server after it's been downloaded.

3. **SMTP**
   The Simple Mail Transfer Protocol (SMTP) is used to deliver email from the sender to an email server, or when email is delivered from one email server to another. SMTP can only be used to send emails, but not receive them.

INTERESTING FACT
Email existed before the World Wide Web. Early email was very simple – it just put a message in another user’s directory in a location they could see when they logged on.

4. Organisation and structure of data

The nature of data

Data is made up of raw facts and figures and can be represented in many different forms including text, numbers, pictures, sounds and video clips. Information can be derived from data when it is processed.

Representation of numbers

You will need to be familiar with three different counting systems. These are denary, binary and hexadecimal.

Denary

The first counting system that you need to be familiar with is the **denary** counting system, also known as the Base **10** or decimal counting system. In the denary counting system, the digits 0_{10}, 1_{10}, 2_{10}, 3_{10}, 4_{10}, 5_{10}, 6_{10}, 7_{10}, 8_{10}, 9_{10} are used to represent numbers. The number 138_{10} for example, actually means 1 'hundred', 3 'tens' and 8 'units'. This gives the total one hundred and thirty-eight:

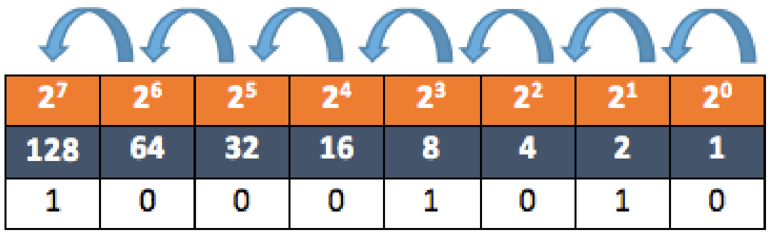
10^2	10^1	10^0
100	10	1
1	3	8

Binary

The second counting system that you need to be familiar with is the **binary** counting system, also known as the Base **2** counting system. In order for data to be processed by a computer system, it must be converted into binary format. This is because computer systems can only store and process **B**inary dig**IT**s, also known as BITs. A BIT is either a 1_2 or 0_2. You may think of this as a light switch, where the switch is either **ON** or **OFF**:

- If the switch is ON it is stored as the digit 1.
- If the switch is OFF it is stored as the digit 0.

A binary number is a string of BITs, for example 10001010_2:

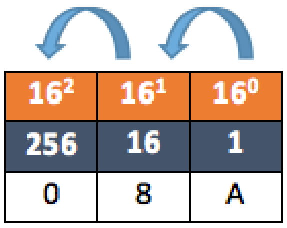


2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	0	0	0	1	0	1	0

The binary number 10001010_2 is therefore a binary representation of the denary number 138_{10} ($128_{10} + 8_{10} + 2_{10}$).

Hexadecimal

The third counting system that you need to be familiar with is the **hexadecimal** counting system, also known as the Base **16** counting system. In the hexadecimal counting system, the digits 0_{16}, 1_{16}, 2_{16}, 3_{16}, 4_{16}, 5_{16}, 6_{16}, 7_{16}, 8_{16}, 9_{16} are used to represent 1–9 and then the characters A_{16}, B_{16}, C_{16}, D_{16}, E_{16} and F_{16} are used to represent 10–15. The hexadecimal number $8A_{16}$ for example:



16^2	16^1	16^0
256	16	1
0	8	A

The hexadecimal number $8A_{16}$ therefore represents 8 'sixteens' and 10 'units'. This gives the total one hundred and thirty-eight. Remember that $A_{16} = 10_{10}$, $B_{16} = 11_{10}$, $C_{16} = 12_{10}$, $D_{16} = 13_{10}$, $E_{16} = 14_{10}$, $F_{16} = 15_{10}$.

INTERESTING FACT

Up until the late 20th century, traditional Chinese weights and measurements used in the marketplace used the hexadecimal counting system. Other cultures used different base counting systems, e.g. the ancient Babylonians used a Base **60** counting system.

The hexadecimal system is widely used as binary numbers can be quickly converted into hexadecimal numbers that are more convenient for humans to use. For example, a telephone conversation where you might read out the binary number 10001010_2 could cause confusion. It's easier to say $8A_{16}$, and mistakes are less likely to be made.

Denary to binary and hexadecimal, binary to denary and hexadecimal, hexadecimal to binary and denary

In this section, we will discuss how to convert between different number systems.

Denary to binary

One way of converting a denary number to a binary number is by drawing a Base **2** table from the right to the left.

128	64	32	16	8	4	2	1

In this example, we will convert the denary number 198_{10} into a binary number. Take 198_{10} and see if it is more than the first number on the left. In this case, 128_{10} is the number on the left and so we write a 1 under the heading 128_{10}.

128	64	32	16	8	4	2	1
1							

We now deduct 128_{10} from our original denary number, which leaves 70_{10}. The next number in our Base **2** table is 64_{10}. If the number remaining, 70_{10}, is more than the next number on the left, 64_{10}, write the number 1 under the heading 64_{10}.

128	64	32	16	8	4	2	1
1	1						

We now repeat the process again and deduct 64_{10} from 70_{10}, which leaves 6_{10}. The next number in our Base **2** table is 32. If the number remaining, 6_{10}, is more than the next number on the left, 32_{10}, write the number 1 under the heading 32_{10}. However, in this case the number remaining is less than the next number on the left, so we write a 0 under the heading 32_{10}.

128	64	32	16	8	4	2	1
1	1	0					

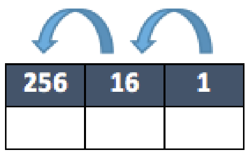
This process is repeated until you reach the final heading and the binary number for the denary number 198_{10} is found:

128	64	32	16	8	4	2	1
1	1	0	0	0	1	1	0

The binary number for the denary number 198_{10} is therefore 11000110_2 (128_{10} + 64_{10} + 4_{10} + 2_{10}).

Denary to hexadecimal

You may wish to convert a denary number into a hexadecimal number. To do this, take the number 198_{10} from our previous example and draw a <u>Base **16**</u> table, from right to left, as before.



256	16	1

Take 198_{10} and see if it is more than the first number on the left. In this case, 256_{10} is the number on the left and so we write a 0 under the heading 256_{10}.

256	16	1
0		

The next number in our <u>Base **16**</u> table is 16_{10}. If the number remaining, 198_{10}, is more than the next number on the left, 16_{10}, work out how many 16s are needed without going over the number remaining. In this case it is C ($C_{16} = 12_{10}$, $12_{10} \times 16_{10} = 192_{10}$).

Remember that $A_{16} = 10_{10}$, $B_{16} = 11_{10}$, $C_{16} = 12_{10}$, $D_{16} = 13_{10}$, $E_{16} = 14_{10}$, $F_{16} = 15_{10}$.

256	16	1
0	C	

We now deduct 192_{10} from our remaining denary number, 198_{10}, which leaves 6_{10}. The next number in our <u>Base **16**</u> table is 1. If the number remaining, 6_{10}, is more than the next number on the left, 1, work out how many 1s are needed without going over the number remaining. In this case it is 6_{10}.

256	16	1
0	C	6

The hexadecimal number for the denary number 198_{10} is therefore $C6_{16}$.

Hint

You may find it easier to convert a denary number into a binary number first and then into a hexadecimal number. See the *binary to hexadecimal* example on the next page.

Binary to denary

To convert a binary number into a denary number, draw a Base **2** table from right to left and populate the table with the binary number you are converting. In this case we will use 00100011_2.

128	64	32	16	8	4	2	1
0	0	1	0	0	0	1	1

Simply convert the binary number into a denary number by adding the headings with a 1 under them: $32_{10} + 2_{10} + 1_{10} = 35_{10}$. The denary number for the binary number 00100011_2 is therefore 35_{10}.

Binary to hexadecimal

To convert a binary number into a hexadecimal number, there is a shortcut that you can use by drawing a Base **2** table from right to left and then populating the table with the binary number you are converting. In this case we will use 00101011_2.

128	64	32	16	8	4	2	1
0	0	1	0	1	0	1	1

Now split the Base **2** table into two smaller 4-bit Base **2** tables.

128	64	32	16
0	0	1	0

8	4	2	1
1	0	1	1

Remember that $A_{16} = 10_{10}$, $B_{16} = 11_{10}$, $C_{16} = 12_{10}$, $D_{16} = 13_{10}$, $E_{16} = 14_{10}$, $F_{16} = 15_{10}$.

Now change the headings of the left hand 4-bit table.

8	4	2	1
0	0	1	0

8	4	2	1
1	0	1	1

2 **B**

Now take the hexadecimal number of each 4-bit table. This is the converted hexadecimal number.

256	16	1
0	2	B

The hexadecimal number for the binary number 00101011_2 is therefore $2B_{16}$.

Hexadecimal to denary

You may wish to convert a hexadecimal number into a denary number. To do this you may take the number $C6_{16}$ and draw a Base **16** table, from right to left as before.

256	16	1
0	C	6

Now multiply each heading to obtain the denary converted number.

$$\begin{array}{rcr} C(12) \times 16 & = & 192_{10} \\ 6 \times 1 & = & 6_{10} \; + \\ \hline & & 198_{10} \\ \hline \end{array}$$

The denary number for the hexadecimal number $C6_{16}$ is therefore 198_{10}.

Hexadecimal to binary

To convert a hexadecimal number into a binary number, there is a shortcut that you can use similar to the one above by drawing two 4-bit Base **2** tables from right to left.

8	4	2	1

8	4	2	1

In this example, we will convert the hexadecimal number $2B_{16}$ into a binary number. First, start by representing the first number, 2, in the left hand table.

8	4	2	1
0	0	1	0

8	4	2	1

Then complete the second table by representing B_{16} in the right hand table. Remember that $B_{16} = 11_{10}$.

8	4	2	1
0	0	1	0

8	4	2	1
1	0	1	1

Now re-label the headings in the left hand table, as shown below, and join the two 4-bit tables together to make one 8-bit table.

128	64	32	16
0	0	1	0

8	4	2	1
1	0	1	1

128	64	32	16	8	4	2	1
0	0	1	0	1	0	1	1

And so, the hexadecimal number $2B_{16}$ can be represented as 00101011_2 in binary number form.

Arithmetic shift functions

Shifts are manipulations of bit patterns. A shift involves moving the bits in a specified direction, either left or right, by a specified number of places, e.g. for an 8-bit register:

Shift left by 2 places of 00110000_2 produces 11000000_2

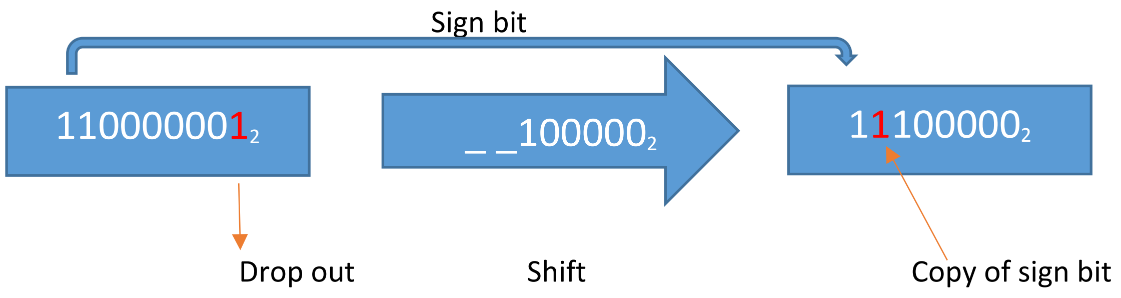
Shift right by 2 places of 00110000_2 produces 00001100_2

Arithmetic shifts can be used for division and multiplication.

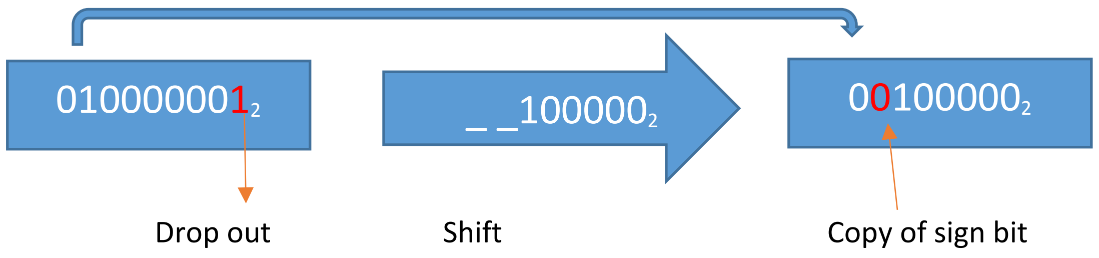
Arithmetic shift right

This operation preserves the sign of a number and will divide a binary number by 2 at each shift. It will work for positive and negative numbers.

At each shift, the right hand bit is lost and a copy of the sign bit is inserted to the left.



Negative integer in Two's complement: - 63_{10} right shift 1 place = - 32_{10}

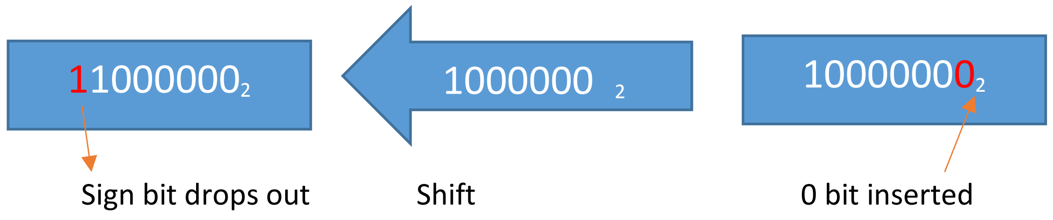


Positive integer in Two's complement: 65_{10} right shift 1 place = 32_{10}

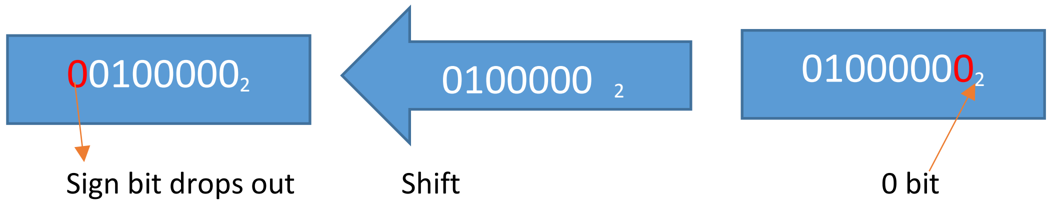
When the right bit has value, i.e. when the shift is applied to an odd number, the result is rounded down to the next even integer.

Arithmetic shift left

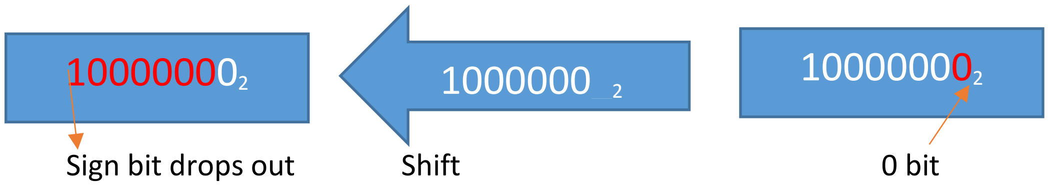
This is similar to a right shift, but at each shift the sign bit is lost and a 0 bit is moved in to the right. The effect of each shift is to multiply the integer x 2. The process can be repeated until the sign bit is changed, at which point overflow occurs.



Negative integer in Two's complement: - 64 left shift 1 place = - 128



Positive integer in Two's complement: 32 left shift 1 place = 64



Positive integer in Two's complement: 64_{10} left shift 1 place = overflow

The shift changes the sign bit and overflow occurs.

Binary Addition

Now we know about binary numbers, we'll learn how to add them.

Binary addition is very similar to your usual everyday addition (decimal addition), except that it carries on a value of 2 rather than a value of 10.

For example: in decimal addition, if you add 8 + 2 you get ten, and write it as 10. In the sum, this gives a digit of 0 and a carry of 1. Something similar happens in binary addition when adding 1 and 1. The result is two (as always), but since two is written as 10 in binary, adding 1 + 1 in binary gives a digit of 0 and a carry of 1.

Therefore in binary addition:

$0_2 + 0_2 = 0_2$

$0_2 + 1_2 = 1_2$

$1_2 + 0_2 = 1_2$

$1_2 + 1_2 = 10_2$ (which is 0 and a carry of 1)

Example

We want to add two binary numbers, 10_2 and 11_2. We start with the last digit. Adding 0_2 and 1_2, we get 1_2 (no carry). That means the last digit of the solution will be one. We then move one digit left: adding 1_2 and 1_2, we get 10_2. Therefore, the solution is 101_2.

Note that the binary numbers 10_2 and 11_2 correspond to 2_{10} and 3_{10} respectively. And the binary total 101_2 corresponds to 5_{10}. Therefore, the binary addition corresponds to our regular addition.

More examples:

Problem: $1_2 + 11_2 = ?$

Solution: $1_2 + 11_2 = 100_2$

Explanation:

		1_2
+	1	1_2

Starting with the right-hand column, we add 1_2 and 1_2 which is:

$1_2 + 1_2 = 10_2 = 0_2$ carry 1

The last (least significant) digit of our solution is therefore 0_2.

Now the second column becomes$0_2 + 1_2 + 1_2$ (as a result of the carry). In binary addition:

$0_2 + 1_2 + 1_2 = 10_2 = 0_2$ carry 1

Therefore, the next digit in our solution is 0_2 and the 1_2 is carried into the next column. There is no next column, so the remaining 1 drops into the next slot in the solution. Therefore, our solution is $1\ 0\ 0_2$.

Problem: $1010_2 + 11_2 = ?$

Solution: $1010_2 + 11_2 = 1101_2$

Explanation:

1	0	1	0_2
+		1	1_2

For the first column, we have (on the right) $0_2 + 1_2$. In binary addition:

$0_2 + 1_2 = 1_2$

Therefore, the last (least significant) digit of our solution is 1_2.

For the second column, we have $1_2 + 1_2$. In binary addition:

$1_2 + 1_2 = 0_2$ carry 1

Therefore, the next digit in our solution is 0_2 and we carry the 1 into the next column. The next column is now $0_2 + 0_2 + 1_2$ (as a result of the carry). In binary addition:

$0_2 + 0_2 + 1_2 = 1_2$

Therefore, the next digit in our solution is 1. The final column now contains $1_2 + 0_2$. In binary addition:

$1_2 + 0_2 = 1_2$

There are no further columns, therefore our solution is $1\,1\,0\,1_2$.

Problem: $100101_2 + 10101_2 = ?$

Solution: $100101_2 + 10101_2 = 111010_2$

Explanation:

	1	0	0	1	0	1_2
+		1	0	1	0	1_2

First column (on the right): $1_2 + 1_2 = 0_2$ carry 1

Second column: $0_2 + 0_2 + 1_2$ (carried) $= 1_2$

Third column: $1_2 + 1_2$ + no carry $= 0_2$ carry 1

Fourth column: $0_2 + 0_2 + 1_2$ (carried) $= 1_2$

Fifth column: $0_2 + 1_2$ + no carry $= 1_2$

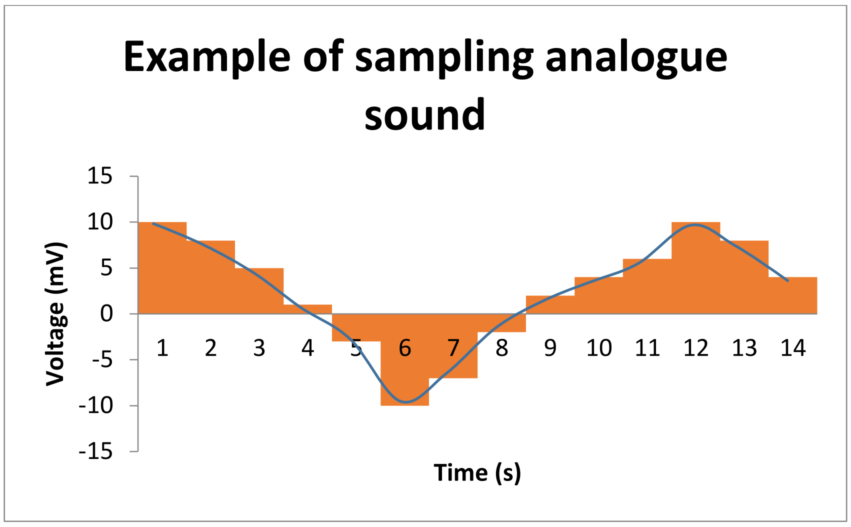
Sixth column: $1_2 + 0_2$ + no carry $= 1_2$

Therefore, the solution is $1\,1\,1\,0\,1\,0_2$.

How sound can be sampled and stored digitally

As we have already established, a computer system is only able to store and process binary digits, as it is a digital device. Since sound is an analogue signal, not digital, how then can it be stored? If an analogue signal, such as sound, is sent to a computer system, it has to be converted into a digital signal before it can be processed.

Sound is converted into a digital signal by a process called *sampling*. This is where hardware, such as a microphone, measures the level of sound many times per second and records this as binary digits.



The number of times that the sound level is sampled per second is called the *sampling frequency*. The higher the sampling frequency, the better the quality of the sound recorded. A typical sampling frequency is 44,000 times per second, also known as 44 kHz. This is the sampling frequency used on most audio CDs.

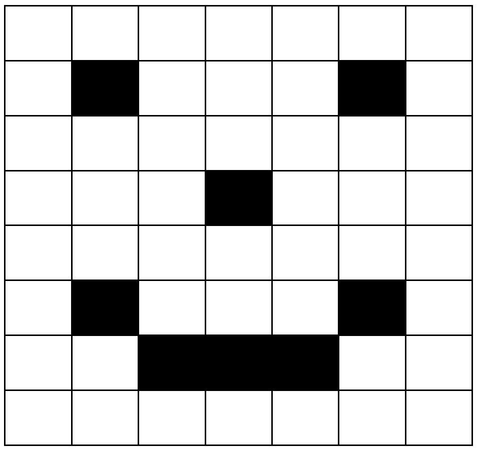
Sound sampled at 44 kHz in stereo will produce a large amount of data and as such, this data may need to be compressed. When sound files are compressed, data is removed to reduce the size.

DIGITAL AUDIO QUALITY

Sample rate – the number of audio samples captured every second.
Bit depth – the number of bits available for each clip.
Bit rate – the number of bits used per second of audio.

How an image is represented by pixels in binary format

Images on a computer system are made up of thousands of small coloured dots, known as pixels (short for picture elements). Bitmap images are stored as an array of pixels. A black and white bitmap image will store a 1 for a black pixel and 0 for a white pixel.



```
0000000
0100010
0000000
0001000
0000000
0100010
0011100
0000000
```

This bitmap image can be represented using 56 bits (or 7 bytes).

A colour bitmap image is stored by replacing the 1s and 0s above with a longer number that represents how much red, green and blue (RGB) is required in the colour of each pixel; this is known as *colour depth*. In a 256-colour palette, the image would require 1 byte of storage per pixel – so we would need 448 bits (or 56 bytes) to store the image above in colour. There are other colour depths available, which can store more information about the colours in each pixel of an image. The more information stored about the colour of each pixel, the larger the file size becomes.

You may also have heard of vector images. These images do not store the data by pixels, but are a set of instructions for drawing a geometric shape. The advantages of a vector image are that they can be scaled without loss of quality (pixilation etc.) and use less storage space.

Images require a large amount of storage space and as such, may need to be compressed.

Why metadata needs to be included in an image file (including height, width, colour depth)

The term metadata refers to ‘data about data’. Key properties that are needed to display an image correctly are stored as metadata. Data such as an image’s height, width and colour depth are typical examples of data stored in an image's metadata. Without metadata, a computer system may render an image incorrectly on screen, such as displaying all pixels in one row.
Other data may also be stored in the metadata of an image file, such as the date the image was made or the geographical location of a photograph.

Binary numbers representing characters

A **character** can be a letter, a digit, a space, a punctuation mark or various other symbols. When characters are stored on a computer system, they are stored as a binary number.

It's important that computer systems recognise that characters can be represented differently by other computer systems; otherwise data could not be exchanged between computers.

The terms ‘character set’, Unicode and ASCII

In order to allow for data exchange between computer systems, **character sets** were devised. A character set is a table that maps a character with a unique binary number.

One such character set is the 7-bit American Standard Code for Information Interchange (ASCII). Part of the ASCII character set, that includes printable characters only, can be seen in the table overleaf.

INTERESTING FACT
Before the widespread adoption of graphical user interfaces, programmers used the ASCII character set to design simple interfaces. Try searching for some on the internet.

Denary	Binary	Hex	Aim
32	100000	20	*space*
33	100001	21	!
34	100010	22	"
35	100011	23	#
36	100100	24	$
37	100101	25	%
38	100110	26	&
39	100111	27	'
40	101000	28	(
41	101001	29	)
42	101010	2A	*
43	101011	2B	+
44	101100	2C	,
45	101101	2D	-
46	101110	2E	.
47	101111	2F	/
48	110000	30	0
49	110001	31	1
50	110010	32	2
51	110011	33	3
52	110100	34	4
53	110101	35	5
54	110110	36	6
55	110111	37	7
56	111000	38	8
57	111001	39	9
58	111010	3A	:
59	111011	3B	;
60	111100	3C	<
61	111101	3D	=
62	111110	3E	>
63	111111	3F	?
64	1000000	40	@
65	1000001	41	A
66	1000010	42	B
67	1000011	43	C
68	1000100	44	D
69	1000101	45	E
70	1000110	46	F
71	1000111	47	G
72	1001000	48	H
73	1001001	49	I
74	1001010	4A	J
75	1001011	4B	K
76	1001100	4C	L
77	1001101	4D	M
78	1001110	4E	N
79	1001111	4F	O
80	1010000	50	P
81	1010001	51	Q
82	1010010	52	R
83	1010011	53	S
84	1010100	54	T
85	1010101	55	U
86	1010110	56	V
87	1010111	57	W
88	1011000	58	X
89	1011001	59	Y
90	1011010	5A	Z
91	1011011	5B	[
92	1011100	5C	\
93	1011101	5D	]
94	1011110	5E	^
95	1011111	5F	_
96	1100000	60	`
97	1100001	61	a
98	1100010	62	b
99	1100011	63	c
100	1100100	64	c
101	1100101	65	e
102	1100110	66	f
103	1100111	67	g
104	1101000	68	h
105	1101001	69	to
106	1101010	6A	j
107	1101011	6B	k
108	1101100	6C	l
109	1101101	6D	m
110	1101110	6E	n
111	1101111	6F	o
112	1110000	70	p
113	1110001	71	q
114	1110010	72	r
115	1110011	73	s
116	1110100	74	t
117	1110101	75	u
118	1110110	76	v
119	1110111	77	w
120	1111000	78	x
121	1111001	79	y
122	1111010	7A	z
123	1111011	7B	{
124	1111100	7C	|
125	1111101	7D	}
126	1111110	7E	~

Using the ASCII character set, the character A would be stored as the binary number 1000001.

The problem with using this ASCII character set is that it's only able to represent 128 different characters. Computer systems need to be able to store more characters than this. For example, you may have noticed that the '£' character is missing from the table above. As a result, other character sets were developed and used to allow computer systems to store more characters.

Unicode is a standard character set that has combined and replaced many others. It was originally an extension to the ASCII character set and it contains many of the characters used around the world – 137,000 characters in total. Each character requires 2 bytes of storage.

Data types

Many different data types can be stored on a computer system. The data types that are most commonly used are as follows:

Data type	Description	Examples
Integer	Whole numbers, positive or negative	**42**, **-11**, **0**
Real	Numbers, including fractions or decimal points	**12.9**, **-17.50**, **28.0**
Boolean	True or false	**1** or **0**
Character	Letter, digit, space, punctuation mark or various other symbols	'**A**', '**b**', '**7**','**?**'
String	A sequence of characters	**'Computer science'** **'The cat sat on the mat'**

Data structures

A data structure is a specific way of organising data within memory so it can be processed efficiently. There will be a relationship between the data items that will vary according to the type of data structure being used.

Static data structure

A static data structure is designed to store a known number of data items. The values of the data can be changed but the memory size is fixed. An array is an example of a static data structure; we can change the values of the elements in the array but we cannot alter the memory size allocated to the array. Memory is allocated at compile-time.

As static data structures store a fixed number of data items, they are easier to program. There is no need to check on the size of the data structure or the number of items stored.

Dynamic data structure

Dynamic data structures are designed to allow the data structure to grow or shrink at runtime. It is possible to add new elements or remove existing elements without having to consider memory space. Memory is allocated at runtime.

Dynamic data structures make the most efficient use of memory but are more difficult to program, as you have to check the size of the data structure and the location of the data items each time you use the data.

List

A list is a data structure that has the data items stored in the order they were originally added to memory. If the list is made up of a set number of data items, it can be a static data structure. If the list can vary in the number of data items, then it will be a dynamic data structure.

Array

An array is a data structure that can hold a fixed number of data items, which must be of the same data type, i.e. real, integer, string etc. The data items in an array are known as elements. An array is an example of a static list.

The elements in an array are identified by a number that indicates their position in the array. This number is known as the index. The first element in an array usually has an index of 0.

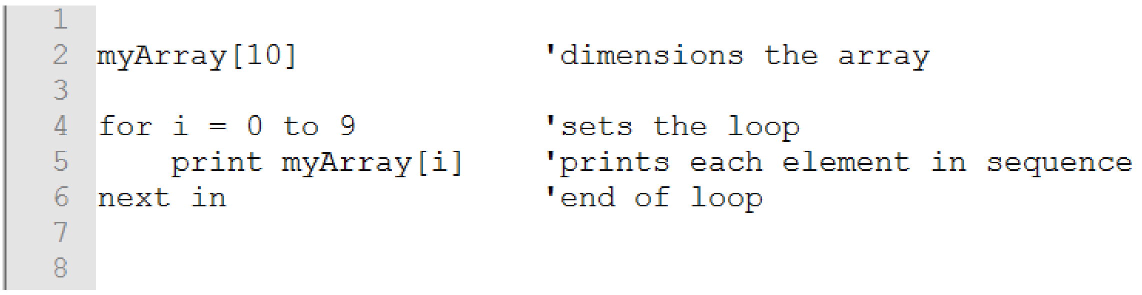
Elements	37	11	42	6	26	56	4	76
Index	0	1	2	3	4	5	6	7

- There are 8 elements in this array.
- The index always starts at position 0.
- Each element can be accessed using its index. The element at index 5 is 56.
- This type of array is known as a one-dimensional array.

Using one-dimensional arrays

A one-dimensional array can be used to store a list of data in memory that can be used by a program at runtime. There are basic operations that can be carried out on data in a one-dimensional array.

- **Traversing** – traversing an array simply means using a loop to use each element of the array in a section of a program. If you wanted to print out the contents of an array called myArray that has 10 elements you would use a ‘for i. . . . next’ loop. Like this:



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myArray[10]                 'dimensions the array

for i = 0 to 9              'sets the loop
    print myArray[i]        'prints each element in sequence
next in                     'end of loop


```

- **Insertion** – you can add an element to an array at a given index.

  myArray[3] = 27

  This would store the value 27 at index 3 of the array.

- **Deletion** – you can delete an element from an array.

  myArray[6] = “”

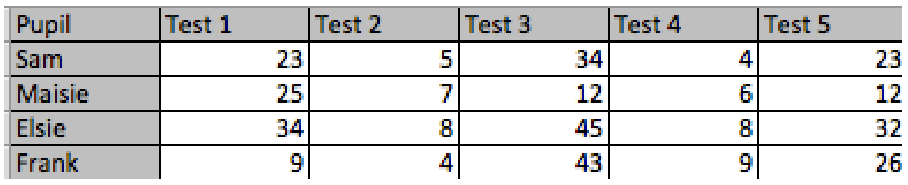
  This would leave the memory at index 6 blank.

- **Searching** – arrays can be searched using the index or the value stored at the index.

Two-dimensional arrays

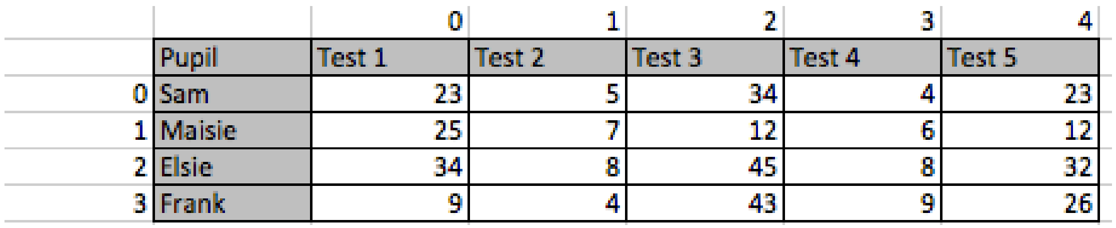
The data we want to process often comes in the form of a table. The data in a two-dimensional array must all be of the same data type.

For example, your teacher may have a spreadsheet of your class’ test results.



Pupil	Test 1	Test 2	Test 3	Test 4	Test 5
Sam	23	5	34	4	23
Maisie	25	7	12	6	12
Elsie	34	8	45	8	32
Frank	9	4	43	9	26

Elements in a two-dimensional array are indexed by two numbers – one for it's row and one for it's column.



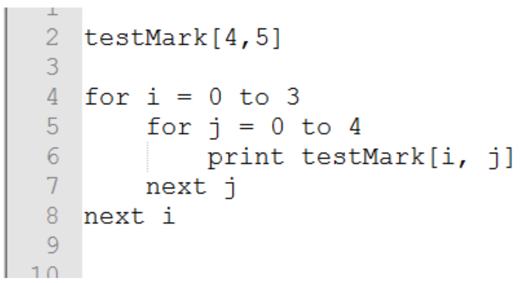
		0	1	2	3	4
	Pupil	Test 1	Test 2	Test 3	Test 4	Test 5
0	Sam	23	5	34	4	23
1	Maisie	25	7	12	6	12
2	Elsie	34	8	45	8	32
3	Frank	9	4	43	9	26

If the two-dimensional array is called testMark, then the command to declare this array would be:

testMark [4,5]

In this declaration, the 4 refers to the number of pupils (rows) and the 5 to the number of tests (columns). The index for Sam’s marks for Test 2 would be [0,1].

To print out the pupils' test marks, you would need to use one loop inside another loop:



```
testMark[4,5]

for i = 0 to 3
    for j = 0 to 4
        print testMark[i, j]
    next j
next i
```

Records

Arrays can only hold data if it is all of the same data type. If you need to hold related data of different data types, you will need to use a data structure called a record. A record will be made up of information about one person or thing. Each piece of information in the record is called a field.

For example, an after school club wants to store data about its members' emergency contact information.

Record Structure

Field Name	Field Type	Example data
Membership number	Integer	1074
First name	String	Sara
Surname	String	Davies
Date of birth	Date	12/07/2004
Contact name	String	Mrs Davies
Contact phone number	String	07564 191919

Key field

Each record in a file should have a key field, namely an item of data that is unique and can be used to identify the individual record. In this example, the membership number would be the key field.

Files

In order for a computer to function, it must have data flowing through the central processing unit (CPU) under the control of a program. More often than not, this data will have come from a stored file.

A program will load the file from secondary storage, such as a hard disk, into the computer's memory. The data will be manipulated by the CPU and then output. The output could be another data file, screen images or a document.

Data stored in a file will have a structure and organisation known as the file format. A data file will be made up of records. It would be most efficient for the fields in a record to be stored next to each other, so the data can be read into the record data structure in memory, for processing by the CPU.

In summary – files are made of records of the same structure and records are made up of fields containing information about one person or item.

Validation

Validation is a process to check that input data is reasonable or sensible. Frequently used validation algorithms include:

Presence checks	Used to prevent further progress if a required field is left blank.
Format checks	Used to ensure data matches a specific pattern, such as dd/mm/yyyy for a date. Input masks are often used to create format checks on database forms.
Length checks	Used to ensure an input data string is a sensible length, e.g. number of characters in 'firstName' to be between 3 and 16
Type checks	Used to ensure input data is a particular data type, e.g. quantity ordered to be integer or cost to be real.
Range checks	Used to ensure input data lies within a specified range, e.g. over time hours to be > 0 and < 15.

Lookup checks can also be used to ensure that input data matches an item in a list of valid entries e.g. input lookup "none"; "vegetarian"; "vegan" will limit the acceptable input to one of three entries.

Verification

Verification is a process for checking data is correct. It can be carried out as a user enters data, via a keyboard for example, and also when data is copied from one part of a system to another. Copying should not change the data.

Examples of verification of user input include double entry and screen based verification.

Double entry involves comparing two versions of data input, e.g. "re-enter your email address". A verification algorithm will compare the two versions and inform the user if they are not identical.

Screen based verification requires the user to check a display of input data and confirm that it is correct.

More sophisticated verification algorithms apply calculations to input data, e.g. to produce the check digits of bar codes. Repeating the calculations and checking the result is the same can verify the data.

Similar verification algorithms, including parity checks and checksums, can be used when sending data between computers, to check that the data has not been corrupted during transmission.

Algorithm design – examples

A. Design an algorithm that will sensibly validate the input data for a diving competition, where entrants must be between 16 and 19 years of age. The competition is to involve 5 dives, with each dive being awarded a score of between 0 and 20.

   The algorithm should verify the entrants' date of birth, check they are eligible for competition and ensure sensible scores are recorded.

B. The table includes input data for a payroll system. Some of the data can be sensibly validated.

Surname	**String**
National Insurance (NI) number	Standard format LL123456L
Job title	Apprentice, semi-skilled, skilled, supervisor
Week no.	Integer
Full time	Y or N, Full time = 38 hours per week
Hours worked	Integer, hours worked in current week, maximum 10 hours overtime in one week. Overtime rate = 1.5 x pay rate
Pay rate	Real, hourly pay rate, max £15.00/hour

Write validation checks that will help ensure sensible input.

5. Operating systems

Managing resources

An operating system is software that manages a computer system. The operating system is loaded by the bootstrap loader. One of its primary functions is to manage resources. Here are some examples of how the operating system manages the computer system's resources.

Managing peripherals such as input and output devices

- Communicates with and sends data output to a printer/monitor/other valid output device.
- Communicates with and receives data input to a keyboard/mouse/other valid input device.

Managing printing using spooling

- Data is stored on a hard disk/in memory/stored in a queue.
- Document is printed when printer is free/in correct order.
- Benefit of spooling – user can carry on working/log off when waiting for job to print.

Managing backing store

- Ensures data is stored and can be retrieved correctly from any disk drive.
- Creates and maintains filing system such asfile allocation table (FAT) or new technology file systems (NTFS).
- Organises files in a hierarchical directory structure.

Managing RAM

- Ensures that programs/data do not corrupt each other.
- Ensures that all programs and data, including itself, are stored in correct memory locations.

Managing processes

- Ensures that different processes can utilise the CPU and do not interfere with each other or crash.
- On a multi-tasking O/S, ensures that all tasks appear to run simultaneously.

Managing security

- Allows creation and deletion of user accounts.
- Allows users to logon and change passwords.

Providing user interface

Another function of the operating system is to provide a user interface. Here are some examples of how the operating system provides a user interface:

- allows copying/deleting/moving/sorting/searching of file or folders
- allows access to system settings such as hardware
- provides a command line interface
- allows users to have more than one window open
- provides a graphical user interface (Windows, Icons, Menus, Pointers)
- provides user with error/help messages
- allows customisation of interface, e.g. change desktop background/layout
- allows user to switch between tasks (programs/windows).

Human-computer interaction (HCI)

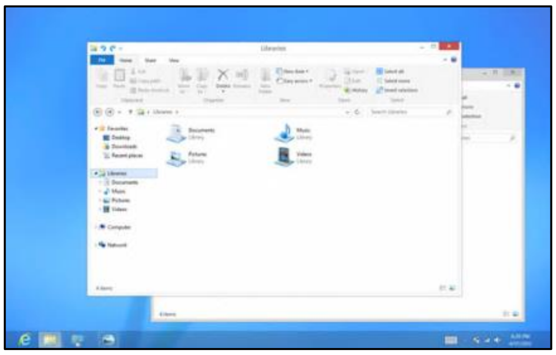
HCI is the term used to describe the communication between people and computer systems. To allow a person and a computer system to communicate, an interface is required, often called a **human-computer interface**.

INTERESTING FACT
The original name for Microsoft Windows' GUI was **Interface Manager**.

Different interfaces are provided by the operating system and can be identified by the style of communication they use. Some are entirely text-based whereas others use images to represent different commands.

Graphical User Interface (GUI)

A GUI is a type of interface that allows users to interact with a computer system through graphical icons.



GUIs were introduced to help users use computer systems, as Command Line Interfaces (CLIs) were very difficult for beginners.

There are many different **features** of a graphical user interface. These include:

- windows
- icons
- menus
- pointers
- assistants/help files/tutorials
- favourites settings/change environment/customisation
- shortcuts/hot keys
- task bar/ribbon bar/tabs/customised toolbar.

Here are some of the advantages and disadvantages of a graphical user interface.

Advantages	Disadvantages
• Intuitive • Easy to navigate • Uses Windows, Icons, Menus and Pointers • No complicated commands • Data between different software applications is easily exchanged	• Requires a large amount of memory • Is relatively processor intensive • Computing experts may find a GUI slower than a CLI • GUIs take up a much larger amount of hard disk space than other interfaces

Menu-driven interface

This type of interface allows people to interact with a computer system by presenting the user with a series of menus, and allowing the user to work through them. The iPod Classic is a perfect example of a device using a menu-driven interface. Users are first introduced to a menu containing a list of artists. Having chosen an artist, another menu appears with a list of albums belonging to that artist. Following this, another menu is presented with a list of songs belonging to the chosen album.

Here are some of the advantages and disadvantages of a menu-driven interface.

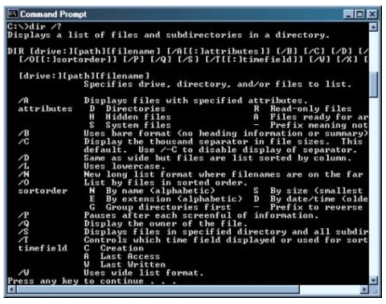
Advantages	Disadvantages
• No need to learn a lot of commands • Intuitive/easy to understand • Easy to navigate • Ideal for beginners – everything is in a logical place/order • No need for expert language to learn • Little processing power needed	• Irritating if there are too many menu screens to work through – users get annoyed or bored if it takes too long • Navigating can be a long process

Voice-driven interface

Voice-driven interfaces, or voice recognition, can be used to issue commands to a computer system and enter data into it. Voice-driven interfaces are popular as it's natural for people to communicate in this way.

Here are some of the advantages and disadvantages of a voice-driven interface.

Advantages	Disadvantages
• Speech input is much faster than keyboard input • No need to learn to type • Less danger of RSI (repetitive strain injury) • Reduces typing mistakes such as spelling/hitting wrong key • Keyboard takes up room on the desk • Users with a disability that prevents typing can use speech input • Hands-free advantages – can multitask • Users find talking more natural than typing	• Background noise interferes with speech recognition • If user has a speech impediment, a sore throat, a cold or a strong accent, they will not be understood • Users with a disability that prevents speech would need to find a different method for input • Difficult to keep data input private as people can hear what you are saying • Words that sound the same, such as ‘too’ and ‘two’ may not be recognised



```
Command Prompt
C:\>dir /?
Displays a list of files and subdirectories in a directory.

DIR [drive:][path][filename] [/A[[:]attributes]] [/B] [/C] [/D] [/
  [/O[[:]sortorder]] [/P] [/Q] [/S] [/T[[:]timefield]] [/W] [/X] [

  [drive:][path][filename]
              Specifies drive, directory, and/or files to list.

  /A          Displays files with specified attributes.
  attributes   D  Directories                R  Read-only files
               H  Hidden files               A  Files ready for ar
               S  System files               -  Prefix meaning not
  /B          Uses bare format (no heading information or summary)
  /C          Display the thousand separator in file sizes.  This
              default.  Use /-C to disable display of separator.
  /D          Same as wide but files are list sorted by column.
  /L          Uses lowercase.
  /N          New long list format where filenames are on the far
  /O          List by files in sorted order.
  sortorder    N  By name (alphabetic)       S  By size (smallest
               E  By extension (alphabetic)  D  By date/time (olde
               G  Group directories first    -  Prefix to reverse
  /P          Pauses after each screenful of information.
  /Q          Display the owner of the file.
  /S          Displays files in specified directory and all subdir
  /T          Controls which time field displayed or used for sort
  timefield   C  Creation
              A  Last Access
              W  Last Written
  /W          Uses wide list format.
Press any key to continue . . .
```

Command line interface (CLI)

A command line interface is an entirely text-based interface that allows a user to communicate with a computer system by typing in commands. However, computer systems will only execute specific commands that are predefined.

Before GUIs were developed, command line interfaces were the most widely used interface.

Here are some of the advantages and disadvantages of a command line interface.

Advantages	Disadvantages
• Quicker to type commands • Quicker to input commands as shortcut keys can be used • Little memory and processing power needed compared with other interfaces • Little storage space is required (no graphical images to store) • Experts who have memorised the commands find it very fast to use	• Very confusing for someone who has never used a command line interface • Commands have to be typed precisely. If there is a spelling error the command will fail • A large number of commands need to be learned • Instructions cannot be guessed • Not suitable for a novice

Touch sensitive interface

Touch sensitive interfaces are becoming more popular and are extensively used in mobile computing devices. Commands are issued or data is input by touching the screen with your finger or a stylus pen. As well as tapping the touch sensitive screen, the screen can interpret other actions made by the user, such as pinching and swiping.

Here are some of the advantages and disadvantages of a touch sensitive interface.

Advantages	Disadvantages
• Very intuitive • Easier to use as the user simply touches what is seen on the display • No keyboard or mouse is required • Touching a visual display of choices requires little thinking and is a form of direct manipulation that is easy to learn • Easier hand-eye coordination than mice or keyboards	• Screen can be easily damaged/scratched • Dirty screens are difficult to read • Users must be within arm's reach of the display • It is difficult to select small items • User's hand may obscure the screen • Screens need to be installed at a lower position and tilted to reduce arm fatigue • Some reduction in image brightness may occur

Disk organisation

File transfer

File transfer is the ability to transfer data from one location to another. This can be done by simply copying a file from one folder to another, or from one storage medium to another. You may wish to carry out either of these tasks in order to organise your files better, using subfolders or to back-up your work onto a secondary storage device, such as a flash memory stick.

Formatting

Formatting is the process of preparing a disk for use. During this process, a new file system is installed on a disk and all data may be erased in readiness for new data to be stored.

INTERESTING FACT
Certain specialist software can be used to "unformat" a formatted disk and recover all the data originally stored on it.

Compression

Compression is the process of making a file size smaller. This may be advantageous as it allows more data to be stored on the disk, and files may also be transferred more quickly. There are two methods of achieving disk compression; one is software based and the other hardware based.

Software based disk compression is often included as a facility of an operating system and so it is readily available on most computer systems. The disadvantage of this is that it slows down the process of reading and writing to disk.

Hardware disk compression requires specialist hardware, which can be expensive. However, it does not affect the speed of access as much as software based disk compression.

Disk based compression is always lossless.

System maintenance tools

Many different system maintenance tools are included with operating systems, that allow users to maintain the upkeep of their computer systems. Here are some of the tools used:

System restore (rollback)

System restore is the process of replacing lost or corrupt data by replacing it with an earlier backup.

INTERESTING FACT
Some modern viruses exploit the system restore facility by deliberately seeking out back-ups and placing copies of themselves there.

Disk defragmentation

Files are stored on computer systems that can, over time, become fragmented. This means they are split and stored on different parts of the disk. If a file is fragmented, it takes longer for the disk heads to move between parts of the file, which slows the process of loading it.

Defragmentation is the process where files are physically re-arranged on disk so they are no longer fragmented, and the parts of each file are stored together. This improves the speed of accessing data from disk.

Control panel

Many operating systems use a control panel to give the user control of software and hardware features. It enables the user to change settings, such as sound, device and display settings, all from one convenient location.

6. Principles of programming

High-level languages

A high-level language is a programming language that allows code to be written. It is similar to a natural human language, such as English. Some programmers prefer to use high-level programming languages, as they are easier to understand, learn and program. Their commands are similar to natural languages like English and identifiers can be long and meaningful. High-level programming languages also allow the use of powerful commands that perform quite complex tasks, such as MsgBox in Visual Basic or the SORT clause in COBOL. Examples of common high-level programming languages include:

- Basic
- Java
- Pascal
- COBOL
- C#
- C++
- Python
- VB

Machine code

Machine code is the opposite of a high-level language, in that it does not resemble any natural language and is made up entirely of bit patterns (instructions or data) that can be executed directly by the CPU. Examples of machine code instructions are opcodes and operands. High-level languages must be converted into machine code before they can be executed by the CPU.

Low-level languages

Programming in a low-level language, such as assembly code, requires knowledge of the internal structure of the CPU and is therefore very specialised. The program statements are written for a particular type of CPU and make direct reference to specific internal registers. Assembly code uses mnemonics and is converted to machine code for execution using an assembler. Source code produced in a low-level language is not portable, but can be very efficient. The programs can be made to run faster than programs produced using a high-level language.

Uses of high-level and low-level languages

High-level languages are used when the execution speed is not the most critical factor, e.g. in common productivity applications, such as a word processor or a spreadsheet. Most modern applications such as commercial database packages, operating systems, e-commerce software and social media apps are developed using a high-level programming language.

Although uncommon, some programmers may wish to program directly in machine code or use assembly code. This is primarily done when programming device drivers or embedded systems, where fast execution speeds are critical. Professional game developers may need to use console specific development software, which is likely to include low-level features for optimum performance.

7. Software engineering

Software development environment

Software development environments, also known as Integrated Development Environments (IDE), provide programmers with various tools that are needed to create computer programs. Here are some of the tools and facilities offered by a typical software development environment.

Facility	Use
Editor	Allows a programmer to enter, format and edit source code.
Compiler	Converts source code into executable machine code. Once compiled, a program can be run at any time.
Interpreter	Converts each line of source code into machine code, and executes it as each line of code is run. The conversion process is performed each time the program needs to be run.
Linker	A program which allows previously compiled code, from software libraries, to be linked together.
Loader	A program which loads previously compiled code into memory.
Debugger	A program which helps locate, identify and rectify errors in a program.
Trace	A facility which displays the order in which the lines of a program are executed, and possibly the values of variables as the program is being run.
Break point	Interrupts a program on a specific line of code, allowing the programmer to compare the values of variables against expected values. The program code can then usually be executed one line at a time. This is called *single-stepping*
Variable watch	A facility that displays the current value of any variable. The value can be 'watched' as the program code is single-stepped to see the effects of the code on the variable. Alternatively a variable watch may be set, which will interrupt the program flow if the watched variable reaches a specified value.
Memory inspector	A facility which will display the contents of a section of memory.
Error diagnostics	Used when a program fails to compile or to run. Error messages are displayed to help the programmer diagnose what has gone wrong.

Libraries

A library is a collection of commonly used private functions and subprograms. Examples of private functions include standard mathematical operations such as square root and random number generators. Examples of subprograms include standard input/output routines, such as saving data to disk. These functions and subprograms can be called from within your program at any stage, but only when the appropriate library has been linked.

Here are the advantages of using standard libraries:

- related private functions and subprograms are stored in the same location
- time is saved as the programmer can simply use the private functions and programs stored in a library
- subroutines contained in a library have already been tested, so they should work reliably and not need further testing
- programs will contain less code and will therefore be easier to maintain.

Most computer languages use standard libraries, although it is also possible to create your own custom libraries.

8. Program construction

Assemblers

An assembler is a program which converts the low-level assembly programming language into machine code. The assembler does this by converting the one-word assembly instructions into an opcode, e.g. converting AND to 0010. It also allocates memory to variables, often resulting in an operand.

Assembly code	Assembler conversion	Opcode	Operand
AND A	→	0010	0001
LOD B	→	0110	0010

Interpreters

Before high-level programming languages can be run, code is converted by an interpreter, one line at a time, into machine code, which is then executed by the CPU.

Compilers

A compiler is used when high-level programming languages are converted into machine code, ready to be executed by the CPU. There are four main stages of compilation:

Lexical analysis

- comments and unneeded spaces are removed
- keywords, constants and identifiers are replaced by 'tokens'
- a symbol table is created which holds the addresses of variables, labels and subroutines

Syntax analysis

- tokens are checked to see if they match the spelling and grammar expected, using standard language definitions. This is done by parsing each token to determine if it uses the correct syntax for the programming language
- if syntax errors are found, error messages are produced

Semantic analysis

- variables are checked to ensure they have been properly declared and used
- variables are checked to ensure they are of the correct data type, e.g. real values are not being assigned to integers

- operations are checked to ensure they are legal for the type of variable being used, e.g. you would not try to store the result of a division operation as an integer

Code generation

- machine code is generated
- code optimisation may be employed to make it more efficient/faster/less resource intense.

Translators

A translator changes (translates) a program written in one language into an equivalent program written in a different language. For example, a program written using the PASCAL programming language may be translated into a program written in one of the C programming languages, using a translator.

Types of error that may occur in programming code

Error	Description	Example
Syntax	An error that occurs when a command does not follow the expected syntax of the language, e.g. when a keyword is incorrectly spelt.	**Incorrect:** IF A ADN B Then **Correct:** IF A AND B Then
Runtime/execution	An error that only occurs when the program is running and is difficult to foresee before a program is compiled and run.	Program requests more memory when none is available, so the program *crashes*.
Logical	An error that causes a program to output an incorrect answer (that does not necessarily crash the program).	An algorithm that calculates a person's age from their date of birth, but ends up giving negative numbers.
Linking	An error that occurs when a programmer calls a function within a program and the correct library has not been linked to that program.	When the square root function is used and the library that calculates the square root has not been linked to the program.
Rounding	Rounding is when a number is approximated to nearest whole number/tenth/hundredth, etc.	34.5 rounded to nearest whole number is 35, an error of +0.5.
Truncation	Truncating is when a number is approximated to a whole number/tenth/hundredth, etc. nearer zero.	34.9 truncated to whole number is 34, an error of –0.9.

INTERESTING FACT
In 1947, Grace Murray Hopper, an admiral in the US Navy and a computer programming pioneer, documented the first actual computer bug when a moth got trapped in a computer.

9. Security and data management

Information stored on computers can be sensitive and needs to be looked after very carefully. This means restricting access to the information. Inappropriate and unauthorised access to this information is likely to have serious consequences and could result in legal penalties, identity theft, financial loss, fraud and invasion of privacy.

Other risks to information stored on computers include loss due to accidental deletion or overwriting parts of files in error; mechanical damage to hard disks, which are the most fragile parts of a computer; power failure whilst work is in progress; accidental damage to hardware, such as fire or damage caused by spilling a drink.

Most of these risks can be managed by adopting efficient procedures for saving work and making regular backups.

Network security

Security is of paramount importance to any network as the loss of data, personal or confidential data in particular, can have many serious consequences. Risks to data become greater as it is shared across a network.

User access levels

It is not desirable that every user should be able to access all the data on a computer system. User access levels are one method used to allow certain users read and/or write access to data on a computer system. For example, in a program used within a company, an administrator, possibly the owner, will have read and write access to all data on the system. An assistant however, will not have access to confidential data such as employees' salaries. User access levels will define which users can change and view, view but not change, or not view stored data.

Suitable passwords

Passwords are commonly used to prove a person's identity to a computer system, thus allowing them access to relevant data.

INTERESTING FACT
The average internet user has 25 online accounts, 6.5 passwords and waits an average of 3.1 months before changing passwords.

Different programs may require a user to use different complexities of password, as well as different character lengths. An example of a simple password may be the user's town of birth, or the word 'password'. A more complex password may require the user to use a combination of upper and lower case alphanumeric characters, for example ‘Pa55word1234’. Increasingly, computer programs require users to use a combination of upper and lower case alphanumeric characters as well as other non-alphanumeric characters such as @ ! ~ - / \ %, for example ‘P@55word/1234!’.

Another user can guess short simple passwords, or a hacker may have access to programs that have the ability to try multiple guesses in quick succession. This is known as a *brute force attack*. Passwords that use a combination of upper and lower case alphanumeric characters as well as other non-alphanumeric character, will be much harder to guess and will take longer to ‘brute force’.

As a rule of thumb, the following formula can be used to determine the number of attempts it would take to brute force a password.

$$Attempts = Number\ of\ characters^{Password\ length}$$

So a password such as ‘computer’ (8 characters), which only contains lower case characters from the 26 letter English alphabet will take:

$$Attempts = 26^8 = 208{,}827{,}064{,}576$$

(on a typical 3.5 GHz computer, this would take less than 6 seconds to brute force)*

Whereas a password that contains upper and lower case alphanumeric characters, such as ‘Computer1’ (9 characters), has 26 + 26 + 10 = 62 possible characters. This will take:

$$Attempts = 62^9 = 13{,}537{,}086{,}546{,}263{,}552$$

(on a typical 3.5GHz computer, this would take just over 1 hour to brute force)*

*assuming one attempt per clock-tick

Encryption techniques

Encryption is the conversion of data, using an algorithm, into a form called cyphertext, that cannot be easily understood by people without the decryption key.

When data is encrypted, a logical operator is sometimes used, called the XOR logical operator.

XOR

The XOR logical operator has two inputs and one output. The output is 1 only if A and B are different.

Input (A)	Input (B)	Output (A XOR B)
0	0	**0**
0	1	**1**
1	0	**1**
1	1	**0**

When encrypting data, the XOR logical operator is performed on the original data and a *key*. The key is a secure binary number, known only to the sender and recipient.

In this example, we will encrypt the data 10101010, using the key 11110000.

Original Data	**10101010**	
Key	**11110000**	XOR
Cyphertext	**01011010**	

The original data, 10101010, is now encrypted and can be transmitted as 01011010.

To recover the original data, the cyphertext is *XOR'ed* with the key.

Cyphertext	**01011010**	
Key	**11110000**	XOR
Original Data	**10101010**	

Other more complex techniques are also used to encrypt data, e.g. SHA256 and Blowfish.

Compression and compression types

Compression is the process of making a file size smaller. This may be advantageous as it allows more data to be stored on the disk, and files may also be transferred more quickly. There are two primary methods that are used to compress files stored on a computer system; these are *lossy* and *lossless*.

Lossless compression

Lossless compression uses an algorithm that compresses data into a form that may be decompressed at a later time without any loss of data, returning the file to its exact original form. It is preferred to lossy compression, when the loss of any detail, for example in a computer program or a word-processed document, could have a detrimental effect.

A simplified version of lossless compression on a word-processed document may to be to replace a common string, such as 'the', with a token such as the symbol @. One character takes 1 byte of memory. Therefore, the string 'the' would take 3 bytes, and the symbol @ would only take 1 byte.

Original uncompressed text	The word the, is the most frequently used word in the English language.	71 characters (bytes)
Compressed text	@ word @, is @ most frequently used word in @ English language.	63 characters (bytes)

This is an 11% reduction in the file size!

Lossy compression

Lossy compression is a technique that compresses the file size by discarding some of the data. The technique aims to reduce the amount of data that needs to be stored.

The following versions of the WJEC logo show how much of the data can be discarded, and how the quality of the images deteriorate as the data that made up the original is discarded. Typically, a substantial amount of data can be discarded before the result is noticeable to the user. The compression ratio is calculated using the simple formula below:

$$Compression\ ratio = \frac{Original\ file\ size}{Compressed\ file\ size}$$

Original image 100 kB	Compressed image 10 kB (compression ratio = 100/10 = 10 or 10:1)	Original image 5 kB
File size	**File size**	**File size**

Lossy compression is also used to compress multimedia data, such as sound and video, especially in applications that stream media over the internet.

Network policies

Acceptable use

Network policies are documents written to outline the rules that users are required to follow while using a computer network. Each document is often several pages long, written and agreed by a committee. Following its publication, network users will be expected to adhere to the rules.

Typical rules set out in these policies include a list of unacceptable types of website that should not be visited and activities that are not allowed on the network, such as gambling and installation of unauthorised software.

Disaster recovery

Given the amount of important data often stored on a computer network, it is essential that an effective disaster recovery policy be in place. Disasters include:

- fire, flood, lightning, terrorist attacks etc.
- hardware failure, e.g. power supply unit failing
- software failure, e.g. virus damage
- accidental and malicious damage, e.g. hacking.

There are usually three parts to a disaster recovery policy:

- **before the disaster:** risk analysis, preventative measures and staff training
- **during the disaster:** staff response – implementing contingency plans
- **after the disaster:** recovery measures, purchasing replacement hardware, reinstalling software, restoring data from backups.

Backups

A **backup** is a copy of data that can be used if the original data is lost.

Backups of all data should be made regularly as the older the backed up data becomes, the less likely it is to match any current data stored on a computer system.

INTERESTING FACT

Key causes of data loss are:

- 78% hardware failure
- 11% human error
- 7% software failure
- 2% computer viruses
- 1% other.

A backup policy sets out how often and to what medium backups are made. The backup medium is generally different to the active storage medium. Historically, the medium used was magnetic tape backup.

A typical backup policy would require that three different backups be kept at any given time, with one of these being stored off-site. The oldest backup copy would be named the *grandfather*, the second oldest backup being named the *father* and the most recent backup being called the *son*. When a new backup is made, the oldest backup, the *grandfather* is overwritten and becomes the *son* backup, with the original son becoming the *father* and the father becoming the *grandfather*. This backup policy is called the *grandfather-father-son* method.

Archiving

Data held on computer systems is often **archived**. Archiving is the process of storing data that is no longer in current or frequent use. It is held for security, legal or historical reasons. The process of archiving data frees up resources on the main computer system and allows faster access to data that is in use.

Cybersecurity

Online networks are vital to many business operations, but they are liable to attacks targeted to access confidential data, such as customers' details or technical information about products, etc. This level of data is very expensive to gather and its loss could result in loss of reputation and even business failure.

INTERESTING FACT
In October 2013, the email addresses and passwords of 150 million users, and credit card data for 2.9 million users, were stolen from Adobe's network.

INTERESTING FACT
The usernames, encrypted passwords and email addresses of 145 million users were stolen from eBay. No payment information was taken.

Cybersecurity refers to the range of measures that can be taken to protect computer systems, networks and data from unauthorised access or cyberattack. Cyberattacks are carried out using various types of **malware** (malicious software), including:

Viruses – programs that can replicate themselves and be spread from one system to another by attaching themselves to host files. They are used to modify or corrupt information on a targeted computer system.

Worms – self-replicating programs that identify vulnerabilities in operating systems and enable remote control of the infected computer.

Spyware – installed by opening attachments or downloading infected software. Spyware can be used to collect stored data without the user's knowledge.

Trojans – programs that appears to perform a useful function, but also provide a 'backdoor' that enables data to be stolen.

Keyloggers are a type of spyware that can be used to track keystrokes and capture passwords and account numbers for fraudulent use.

Parents can use keylogger software to monitor their children's online activity.

Protection against malware

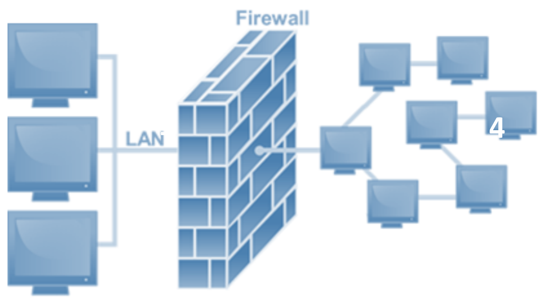
Install virus protection software, also called anti-virus software. This is a program that can be loaded into memory when the computer is running. It monitors activity on a computer system for the signs of virus infection. Each virus has its own unique 'signature' that is known to virus protection software and stored in a database. Data stored on a computer system is scanned to see if any of the virus signatures within the database exist on the system.

INTERESTING FACT
Some advanced viruses attempt to evade the virus protection software by changing their own code so they no longer match the "signature" in the virus signature database.
These are known as *polymorphic viruses*.

There are many thousands of known viruses, and new viruses are created daily. Virus protection software therefore needs to be updated regularly to combat these.

Use a firewall. A firewall can be a software or hardware security system that controls the incoming and outgoing network traffic. Packets of data are analysed to determine whether they should be allowed through or not.

The internet



The basic function of a firewall is to monitor where data has come from and where it is going, and determine if this communication is allowed. It does this by checking a list of pre-defined rules.

INTERESTING FACT
In May 2017 the NHS was attacked by the WannaCry virus (WanaCrypt0r 2.0 / WCry). This infection held user files at ransom. It happened because NHS systems were still using Windows XP which had gone out of date in 2014.

Keep your operating system up to date. New ways to bypass the operating system's built-in security are often discovered and can be covered by installing the security patches issued by the operating system manufacturer.

Use the latest versions of web browsers. As with operating systems, the manufacturers of web browsers seek to continually improve their products and remove possible security vulnerabilities. Most browsers will download updates automatically, but will need a restart for the update to be installed.

Look out for phishing emails. Emails that ask you to confirm personal details are usually fakes. They should be caught by the spam filter, but be suspicious and do not provide any sensitive information.

If you suspect you have malware on your computer you will need to download and run a **malicious software removal tool** that should detect and remove malware not blocked by the anti-virus software.

Forms of cyberattack

Internet protocols, operating systems and network equipment all present inherent technical weaknesses that must be recognised and protected against. User behaviour can also compromise security, e.g. sending sensitive documents to unintended recipients, opening malicious attachments to scam emails or using the same passwords for multiple systems. Specific forms of attack include:

Shoulder surfing – using direct observation to get information. It is relatively simple to stand next to someone and watch as they fill out a form, or enter a PIN number, but shoulder surfing can also be carried out long distance with the aid of binoculars or even CCTV.

SQL injection – a technique where malicious users can inject SQL commands into an SQL statement, via web page input. Injected SQL commands can alter SQL statements and compromise the security of information held in a database.

Denial of service (DoS) attacks – they do not attempt to break system security, they attempt to make your website and servers unavailable to legitimate users, by swamping a system with fake requests – usually in an attempt to exhaust server resources.

A DoS attack will involve a single internet connection. Distributed denial of service (DDoS) attacks are launched from multiple connected devices that are distributed across the internet. These multi-person, multi-device attacks target the network infrastructure in an attempt to saturate it with huge volumes of traffic.

Carphone Warehouse data breach DDoS – 2015

In July 2015, major UK smartphone retailer Carphone Warehouse suffered a serious data breach. It later transpired that this might have been aided using a DDoS 'distraction' attack. Up to one in five DDoS incidents are later found to be part of a data theft snatch in which IT staff are occupied fending off the DDoS, giving attackers more opportunity to sneak in and out.

Password-based attacks – passwords are a good starting point, but are they secure? Cyber criminals have ways of finding out your password.

Dictionary attack	This uses a simple file containing words found in a dictionary. This attack uses exactly the kind of words that many people use as their password.
Brute force attack	Similar to the dictionary attack but able to detect non-dictionary words by working through all possible alphanumeric combinations from aaa1 to zzz10. It’s not quick, but it will uncover your password eventually.
Guess	A user-generated password is unlikely to be random. Passwords are likely to be based upon our interests, hobbies, pet names, family names etc. Educated guesses often work.

IP spoofing – a spoof is a hoax, or a trick. IP address spoofing involves an attacker changing the IP address of a legitimate host so that a visitor who types in the URL of a legitimate site is taken to a fraudulent or spoofed web page. The attacker can then use the hoax page to steal sensitive data, such as a credit card number, or install malware.

Social engineering – internet users frequently receive messages that request password or credit card information to “set up their account”. Social engineering involves tricking a user into giving out sensitive information such as a password, by posing as a legitimate system administrator.

Examples of social engineering attacks carried out by deception include phishing, which is an attempt to acquire users’ details using fake emails and websites, and pharming, where users are unknowingly re-directed to a fake website, again with the intention of committing identity theft.

Identifying vulnerabilities

Footprinting – this is the first step in the evaluation of the security of any computer system. It involves gathering all available information about the computer system or network and the devices that are attached to it. Footprinting should enable a penetration tester to discover how much detail a potential attacker could find out about a system and allow an organisation to limit the technical information about its systems that is publicly available.

Ethical hackings – this is carried out with the permission of the system owner to cover all computer attack techniques. An ethical hacker attempts to bypass system security and search for any weak points that could be exploited by malicious hackers. This information is then used by the system owner to improve system security.

Penetration testing – this is a subset of ethical hacking that deals with the process of testing a computer system, or network, to find vulnerabilities an attacker could exploit. The tests can be automated with software applications or they can be performed manually. Penetration testing strategies include:

- targeted testing – testing carried out by the organisation's ITC team and the penetration testing team working together
- external testing, to find out if an outside attacker can get in and how far they can get in once they have gained access
- internal testing, to estimate how much damage a dissatisfied employee could cause
- blind testing, to simulate the actions and procedures of a real attacker by severely limiting the information given to the team performing the test.

Protecting software systems

Secure by design

This is an approach that seeks to make software systems as free of vulnerabilities as possible through such measures as continuous testing and adherence to best programming practices. At the design stage, malicious practices are taken for granted and it is assumed that the new system will have invalid data entered or will be the subject of hacking attempts. These issues are taken into account and corresponding security measures are considered to ensure security is not an afterthought. This reduces the need for addressing vulnerabilities and patching security holes as they are discovered in use.

Some examples of attacks that should be prevented during design and testing include:

Buffer overflow attacks – a buffer overflow occurs when a program tries to store more data in a buffer (temporary data storage area) than it was intended to hold. This may occur accidentally through programming error, or it may be caused intentionally in a buffer overflow attack, where the overflow data may contain codes designed to change data, or disclose confidential information. Thorough testing, particularly of any library routines used, will help prevent this type of attack.

Permissions – every time you want to install an app, you are asked to give permission for the software to access certain settings and features of your device, e.g. the Facebook Messenger App, which boasts over 1,000,000,000 downloads, requires permission to access a large amount of personal data and requires direct control over your mobile device. It is unlikely that many of those who downloaded this app read the full 'Terms of Service' before accepting them. It is not always easy to understand what you are permitting an app to do. Should you uninstall an app because its permissions are suspicious?

App developers are keen to develop interactive products that are useful, but they need to consider the scope of access and limit the number of permissions required at the design stage. There are malicious apps, but you can avoid them by using common sense.

Scripting restrictions – Same Origin Policy (SOP) is a security measure that prevents a website's scripts from accessing and interacting with scripts used on other sites. Running scripts from other sites would be dangerous because a malicious script from a compromised site could interact with a script from a legitimate site without restriction, potentially leading to malware infections or sensitive data being compromised.

A programmer can control the range and type of scripts allowed by setting the restrictions in an HTML web page header for example, or by using standard script execution settings such as unrestricted, trusted, restricted etc.

Accepting parameter without validation – dynamically generated HTML web pages can introduce security risks if inputs are not validated on the way in. Malicious script can be embedded within input that is submitted to web pages and this could then appear to browsers as originating from a trusted source.

Approaches to prevent this type of cross-site scripting attack rely on the design of validation rules that will check and filter input parameters.

The role of cookies

Cookies are data stored on a computer system. They allow websites to store a small amount of uniquely identifying data on your computer system while you are visiting. This may be useful as the website can then identify you in future without requesting that you identify yourself each time, i.e. by entering a username and password. Another use of a cookie would be when adding items to a shopping basket over a period of time. The cookie allows you to store this information between separate browsing sessions.

10. Ethical, legal and environmental impacts of digital technology

Ethics is the branch of philosophy that is concerned with right and wrong. What is good for an individual and what is good for society as a whole? Developments arising from computer science and the resulting digital technologies produce ethical implications for individuals and society. These implications are not always obvious and sometimes lead to unanticipated problems.

The Digital Divide

The digital divide is a term that refers to the gap between populations that have full access to modern information and communications technology, and those who have restricted access. It is used mainly to describe the split between those with and those without broadband internet access.

The divide traditionally exists between those in cities and those in rural areas; between the educated and the uneducated; between socioeconomic groups; and globally, between the more and less industrially developed nations. Even among populations with some access to technology, the digital divide can be evident in the form of lower-performance computers and lower-speed connections.

The next billion people coming online will do so from cheap mobile phones. While the cost of phone services is falling globally, fixed broadband which is typically more reliable and faster than cellular connections, is becoming more expensive in the poorest countries.

Some UN statistics from 2015:

- For the least developed countries, the average broadband cost grew by more than 30%, “a sharp increase that will certainly not improve the already very low uptake of fixed-broadband in the world’s poorest countries.”
- 43.4% of the world’s population used the internet in 2015, but that figure fell to 9.5% for the least developed countries.
- Women in low and middle income countries were 21% less likely to own a mobile phone, helping perpetuate inequality between men and women.
- 8% of females used the internet in 2015 compared with 11.3% of males.

The UN has set goals for broadband services to cost no more than 5% of average monthly incomes in developing countries by 2020, and to achieve gender equality among internet users by 2020.

Do you think achieving these the goals will be enough to close the digital divide?
Who should provide the technology and meet the cost?

The 'World Development Report 2016: Digital Dividends' from the World Bank (http://www.worldbank.org/en/publication/wdr2016) says:

"Digital technologies have spread rapidly in much of the world. Digital dividends – that is, the broader development benefits from using these technologies – have lagged behind. In many instances, digital technologies have boosted growth, expanded opportunities, and improved service delivery. Yet their aggregate impact has fallen short and is unevenly distributed. For digital technologies to benefit everyone everywhere requires closing the remaining digital divide, especially in internet access. But greater digital adoption alone will not be enough."

What other measures will be required to close the digital divide?

Some example discussion topics

Drones

The idea of remotely controlled unmanned vehicles flying through the air either raises concerns over personal privacy, or leads us to consider citizens who live in fear of drones used for military purposes.

NASA have successfully tested a prototype system that allows unpiloted drones to detect and avoid other aircraft in their midst. The agency's drones are able to sense when something was in their flight path and make adjustments on their own.

In the UK, the Civil Aviation Authority is warning that drones being flown as high up as 2,000ft are putting passenger aircraft in danger. Drones can be used to monitor pollution levels and track wildlife poachers. Should their use be controlled?

Self-driving cars

Standard features on many ordinary cars include intelligent cruise control, parallel parking programs, and even automatic overtaking – features that allow you to sit back and let a computer do the driving.

Many car manufacturers are beginning to design cars that take the driving out of your hands altogether. It is claimed that these cars will be safer, cleaner, and more fuel-efficient than their manual counterparts, but can they ever be perfectly safe?

The idea of the computer controlling the car raises some ethical questions. How should the computer be programmed to act in the event of an unavoidable accident? Should it minimize the loss of life, even if it means sacrificing the occupants, or should it protect the occupants at all costs?

Artificial Intelligence

Google's AlphaGo computer learned to play Go at an expert level by watching people compete and then simulating millions of its own games against itself. It eventually became good enough to defeat even the best software that had been pre-programmed to play Go. In October, Google pitted AlphaGo against Fan Hui, the best player in Europe. They played five games. The computer won all of them. In 2016 AlphaGo defeated multiple world champion Lee Sedol, 4 games to 1.

Neuromorphic chips configured more like brains than traditional chips make computers far more astute about what is going on around them – computers that learn by experience. New generation robotics can react without pre-programming. The possibility of creating thinking machines raises a host of ethical issues relating both to ensuring that such machines do not harm humans and to the moral status of the machines themselves. If something goes wrong who is responsible? Should it be the robot's programmer, designer, manufacturer, human overseer or his superiors?

Issues of privacy and cybersecurity

Causes of loss of privacy:

- The monitoring of online activity, including browsing histories and use of social media.

> **Consider.** In 2014, the world discovered that the US security agency NSA had been spying on the communications of millions of its own citizens. In 2014 the UK government amended the Computer Misuse Act to provide a new exception for law enforcement and GCHQ to hack without criminal liability. This was done without public consultation or any debates over mass surveillance.

- The interception and reading of email messages.

One ethical problem that relates to the private communications of an individual involves the interception and reading of email messages which is often justified in terms of security.

- Distribution of databases storing personal information.

The individual may not be aware of the extent of the personal information being distributed, or who has access to the database, or whether the information is accurate.

> **Consider.** Genome-based treatment, based on wider and cheaper availability of genome data, will provide new and personalised ways of fighting life-threatening diseases. However, privacy risks associated with data storage of genome data will invariably arise, particularly as such databases are often shared for security reasons (for example, between international police forces), increasing the possibility of hacking or abuse by authorities.

- Theft of private information by hackers.

> November 2014 – hackers leak a release of confidential data from Sony Entertainment, including personal information about employees and their families, salaries, internal emails and copies of unreleased films.

In the handling and processing of private and personal information organisations are confronted with several ethical issues:

- deciding on the scope of personal and private information they can gather
- the confidential treatment of such information
- the accuracy of information – who checks that the information is correct
- the purposes for which various categories of information may be used
- the rights of a person – the question of consent.

February 2016 – there was confrontation between Apple and the FBI over a dead terrorist's iPhone. The FBI wanted Apple to write new code that would unlock an iPhone belonging to a dead terrorist. Apple refused, arguing they should not be forced to weaken the iPhone's encryption in the name of national security, as this would compromise the privacy of its customers and the strength of its product security.

Codes of Conduct

A code of ethics, or code of conduct, defines acceptable behaviour within an organisation. Higher standards are generally promoted when a code of ethics is accepted and followed by members of an organisation. It is useful as individuals working for the organisation have a benchmark upon which they can judge their own behaviour and that of others.

Informal and formal codes

Most small organisations do not have a formal written code of ethics. Instead, they rely on senior members of staff to lead by example, showing what acceptable behaviour is. Members understand the informal code by observing how senior members conduct themselves, e.g. the type of language used in emails and behaviour towards clients.

Formal codes are written documents that outline expected behaviours within an organisation. Formal codes of ethics are usually enforced by the threat of disciplinary action should the code not be adhered to. Each code of ethics is different and usually reflects an organisation's ethos, values and business style. Some codes are short and set out general guidelines, whereas other codes are large documents that include a variety of aspects relating to an organisation's values, ethics, objectives and responsibilities.

An individual's own personal code

An individual's own personal code often supersedes the bare minimum requirements of an organisations ethics code. An individual's own personal code will vary from person to person as they choose to act upon their own ethical standards in their everyday actions.

Legislation relevant to computing

Many pieces of legislation govern the use of computer systems. Relevant examples of legislation include:

- The Computer Misuse Act (CMA) 1990
- The Freedom of Information Act 2000
- The Regulation of Investigatory Powers Act (RIPA) 2000
- The General Data Protection Regulation (GDPR) 2018

The Computer Misuse Act (CMA) 1990

When the use of computer systems became widespread, the Computer Misuse Act (CMA) 1990 was put in place to help combat issues arising from their misuse.

The Act makes it an offence to:

- access data without permission, e.g. looking at someone else's files
- access computer systems without permission, e.g. hacking
- alter data stored on a computer system without permission, e.g. writing a virus that deliberately deletes data.

The Freedom of Information Act 2000

The main principle behind freedom of information legislation is that people have a right to know about the activities of public authorities, unless there is a good reason for them not to have this information.

Most countries operate some form of freedom of information law. In the UK it is the Freedom of Information Act 2000. The Act provides public access to information held by public authorities in two ways:

1. Public authorities are obliged to publish certain information about their activities.
2. Members of the public are entitled to request information from public authorities.

The Act covers any recorded information that is held by a public authority in England, Wales and Northern Ireland, and by UK-wide public authorities based in Scotland.

There are some exemptions, including information held for criminal investigations or relating to correspondence with the royal family, and where disclosure may cause a specific type of harm, such as endangering health and safety, prejudicing law enforcement or prejudicing someone’s commercial interests.

The Regulation of Investigatory Powers Act (RIPA) 2000

The Regulation of Investigatory Powers Act (RIPA) 2000 is an Act that regulates the powers of public bodies to carry out surveillance and investigation. It also regulates the interception of communications.

The purpose of the Act is to provide clear legal guidelines for organisations, such as the security services and the police, to carry out surveillance and access the digital communications of individuals, such as email, telephone calls, text messages etc. It also makes it a crime for anyone who is not authorised under the Act to carry out surveillance and monitoring of communications.

The aim of allowing certain organisations to intercept communications is to:
- prevent or detect crimes
- prevent public disorder from occurring
- ensure national security and the safety of the general public
- investigate or detect any abnormal or illegal use of telecommunication systems.

Concerns around privacy

Only nine organisations, including the police and the Ministry of Defence, were allowed to intercept and monitor electronic communications when the Act was originally passed in 2000. Thousands of organisations now have this right.

There are a number of people who regard the RIPA as a threat to our privacy. There are increasing concerns that the RIPA is being misused by organisations, and that it no longer adheres to its original purpose of primarily upholding the law and protecting national security.

The General Data Protection Regulation (GDPR) 2018

In 2018, the Data Protection Act 1998 was repealed and replaced with the GDPR 2018; a new european-wide law that sets out data protection principles and the main responsibilities of organisations who store data.

The GDPR applies to all ‘personal data’. Personal data is classed as any information relating to a person who can be directly or indirectly identified.

This definition provides for a wide range of personal identifiers that constitute personal data, including name, identification number, location data or an online identifier, reflecting changes in technology and the way organisations collect information about people.

Principles

The GDPR requires personal data to be:

- processed lawfully, fairly and in a transparent manner in relation to individuals
- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which it is processed
- accurate and, where necessary, kept up to date; every reasonable step must be taken to ensure that inaccurate personal data, with regard to the purposes for which it is processed, is erased or rectified without delay
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the personal data is processed
- processed in a manner that ensures appropriate security of the personal data, including protection against unauthorised or unlawful processing and against accidental loss, destruction or damage, using appropriate technical or organisational measures.

The individual's rights

The GDPR provides the following rights for individuals.

1. The right to be informed
    - Individuals have the right to be informed about the collection and use of their personal data.
    - Organisations must provide individuals with information including the purpose of processing their personal data, retention periods for that personal data, and who it will be shared with.

2. The right of access
    - Individuals have the right to access their personal data. They can request the data verbally or in writing.
    - Organisations have one month to respond to a request.
    - Organisations cannot charge a fee to deal with a request in most circumstances.

3. The right to correction
    - The GDPR includes the right for individuals to have inaccurate personal data corrected, or completed if it is incomplete.

4. The right to erasure
    - The GDPR introduces the right for individuals to have personal data erased. This right is also known as 'the right to be forgotten'.

- Individuals can request erasure of their data verbally or in writing.

5. The right to restrict processing
    - Individuals have the right, in certain circumstances, to request the restriction of their personal data.
    - When processing is restricted, organisations are permitted to store the personal data, but not use it.

6. The right to data portability
    - The right to data portability allows individuals to obtain and reuse their personal data for their own purposes across different services.
    - It allows them to move, copy or transfer personal data easily from one IT environment to another in a safe and secure way, without affecting its usability.
    - Doing this enables individuals to take advantage of applications and services that can use this data to find them a better deal or help them understand their spending habits.

7. The right to object
    - The GDPR gives individuals the right to object to the processing of their personal data in certain circumstances.
    - Individuals have an absolute right to stop their data from being used for direct marketing purposes.
    - Organisations must tell individuals about their right to object.

8. Rights in relation to automated decision making and profiling
    - The GDPR has provisions for making a decision solely by automated means, without any human involvement.
    - Individuals also have rights regarding profiling, which is the automated processing of personal data to evaluate certain things about an individual.

Exemptions

There are several exemptions that can apply to the GDPR, where it is a necessary and proportionate measure to safeguard the following:

- national security
- defence
- public security
- the prevention, investigation, detection or prosecution of criminal offences
- other important public interests, in particular economic or financial interests, including budgetary and taxation matters, public health and security
- the protection of judicial independence and proceedings

- breaches of ethics in regulated professions
- monitoring, inspection or regulatory functions connected to the exercise of official authority regarding security, defence, other important public interests or crime/ethics prevention
- the protection of the individual, or the rights and freedoms of others, or the enforcement of civil law matters.

Environmental impacts

The technologies we use every day consume a lot of resources and power and can present health hazards such as obesity and RSI arising from technology addiction.

Building the hardware can cause harm to the environment, including air, water, heat and noise pollution arising from manufacturing processes and the use of non-renewable resources, including precious metals such as gold used in circuitry.

Carbon emissions are released into the atmosphere when electricity created from burning fossil fuels is used. Creating electricity takes a lot of resources, and it can be expensive to use it. It is sensible to reduce how much you use, by taking measures, such as:

- turning off computers and peripherals when not in use
- adjusting the settings of your power options to help minimise power consumption
- choosing more energy efficient and environmentally friendly options, e.g.:
    - laptop computers use 75% less power than desktop machines
    - monitors account for up to half of the energy used by a computer, and the larger the monitor, the more power it uses
    - ink jet printers use about 90% less energy than laser jets
    - any product that earns the Energy Star label uses 30% to 75% less electricity than a standard product.

Landfill

Old computers get thrown out when they become out-dated. They contain all sorts of hazardous materials that need to be disposed of using special methods. Otherwise, the waste would become landfill.

Most electronics contain non-biodegradable materials and heavy metals and toxic materials like cadmium, lead and mercury. Over time, these toxic materials can leak into the ground, where they can contaminate water, plants and the animals that live around the area. Many countries have banned technology products from landfills.

Increased populations

The negative impacts of technology on society include increased pollution and the depletion of scarce resources. A further negative impact arises from improving health research, helping people to live longer, resulting in an increase in population.

This is good news for people in developed countries, but causes problems in developing countries that may not be in a position to access the healthcare benefits brought about by technology. In these countries, mortality rates remain high, food is scarce and healthcare is poor.

Repair or Recycle?

Before throwing away old computers or mobile devices, consider repairing or recycling them. There are many charities that will try to refurbish and repair old computer equipment and then donate the equipment to worthwhile causes, either at home or abroad.

Repairing prolongs the life of the equipment, delaying the need to manufacture a replacement. Recycling is also an environmentally friendly solution that allows components, such as precious metals, to be retrieved and reused.

Before donating a machine for repairing or recycling it is important to remove all your files and data from it. The recycle bin only partially removes the information – you need to run a special program that erases your hard drive.

Waste from paper and packaging

You can reduce waste paper by thinking twice about printing documents, email messages, pictures and things you find on the Web. Buy paper that is made from recycled products and recycle the paper you use. Software companies are reducing their waste by offering their products as an online download instead of selling it in a box.

Positive impacts of technology on the environment

Advances in computer technology have produced many positive impacts on society, including:

- the development of new materials and processes that are sustainable and do not harm the environment
- enabling the study of our environment to better understand how it works and the impact of our actions on it
- smarter technologies that respond to how we use them and adjust themselves to reduce their environmental impact
- helping experts from all fields share their research, experience and ideas to come up with better solutions
- communications that reduce the environmental impact people would normally have due to traveling
- improved education, including distance learning and visual learning using integrated technologies.

Unit 2

1. Problem Solving

Programmers can only write programs for computers to solve problems if they understand how to solve the problem themselves. This means that a programmer has to have a toolkit of different methods they can use to consider the ways in which the problem can be solved.

To write successful problem solutions, programmers must develop good computational thinking skills that will help them break the problem down into manageable chunks and simplify the situation.

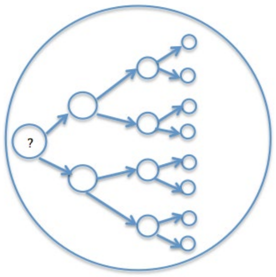
Computational thinking

To be able to represent a problem as a set of steps that can be carried out by a computer requires good computational thinking skills. These steps could be presented as algorithms.

Decomposition

Programmers use a technique called decomposition to break a large program down into a series of sub-problems.

The starting point is to decompose the large problem so that each sub-problem is described in the same level of detail and can be solved independently from the other sub-problems. The solutions to the sub-problems can then be brought together to provide a solution to the whole problem.



One of the advantages of decomposition is that different people can work on different sub-problems. However, a disadvantage would be that the solutions to the sub-problems might not come together to provide a solution to the whole problem.

Example problem

A school has decided to introduce a smart card system for its pupils to pay for food and drinks in the school's dining hall. It has asked a programmer to design the system for the school.

The whole problem is the introduction of the smart card system but the programmer must break the problem down into manageable chunks. The system must be able to:

- allow parents to add money to their child's smart card
- allow pupils to pay for their food and drink
- update the amount of money remaining on the card.

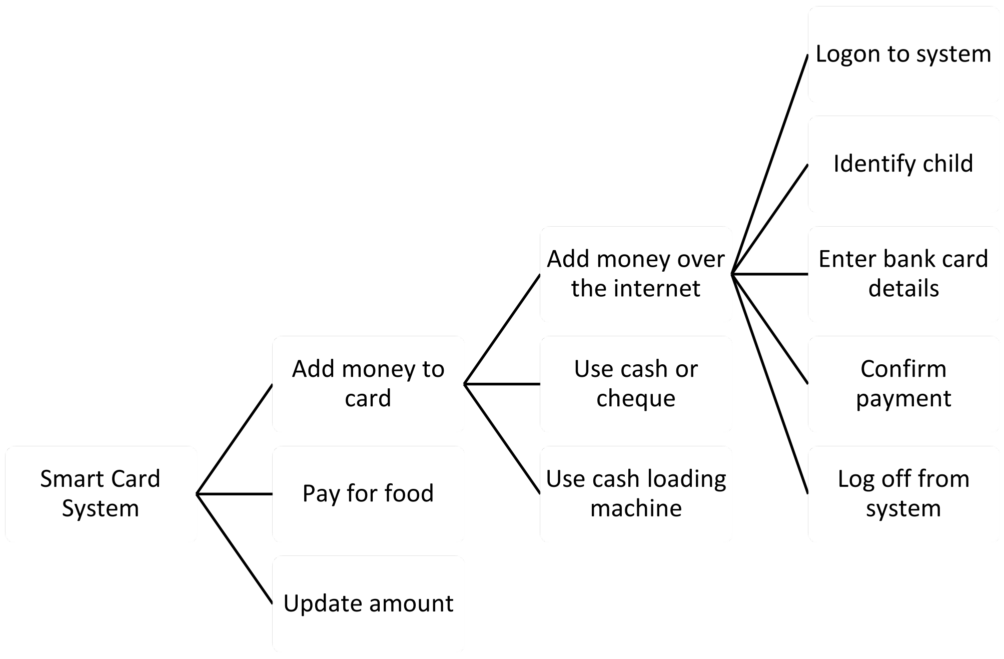
So now the programmer has three sub-problems, but each of the three is quite complex and can be broken down further.

'Allow parents to add money to their child's smart card' can be broken down into the following problems:

- add money over the internet
- add money by giving cash or a cheque to the pupil, to take to the school office
- add money by allowing the pupil to use a cash-loading machine in the dining hall.

'Add money over the internet' can be broken down into the following problems:

- logon to the school's payment system
- identify the child who uses the smart card
- enter the details of the bank card to be used for payment
- confirm the payment
- logoff from the school's payment system.

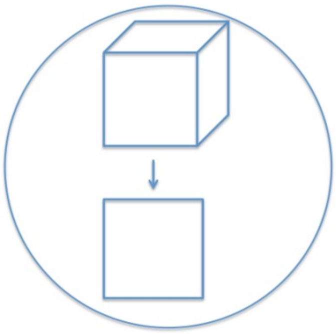


This process has broken part of the problem into distinct sub-problems that can be solved and combined to form part of the solution to the original problem.

Abstraction

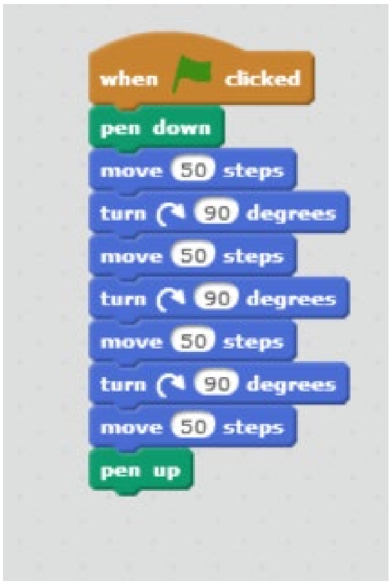
Abstraction is a technique to reduce something to the simplest set of characteristics that are most relevant to solving the problem.

The programmer has to concentrate on the most important aspects of the problem without worrying about fine details.



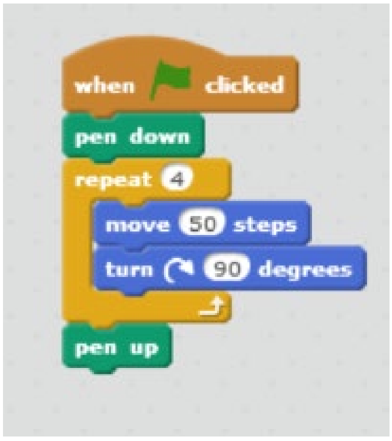
A simple example of abstraction

I want to create a program to draw a square in Scratch. The square must have four sides of 50 units with an angle of 90^o between each side. The code in Scratch looks like this:



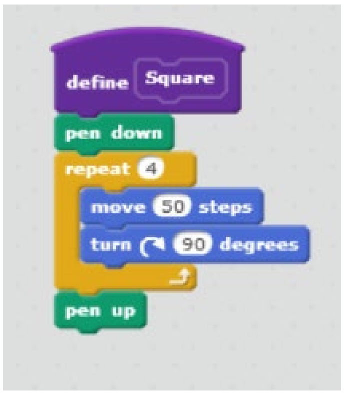
```
when [flag] clicked
pen down
move 50 steps
turn ↻ 90 degrees
move 50 steps
turn ↻ 90 degrees
move 50 steps
turn ↻ 90 degrees
move 50 steps
pen up
```

There are a lot of repeated commands in the code. It can be simplified by using a loop for the repeating code.

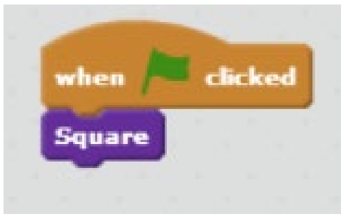


```
when [flag] clicked
pen down
repeat 4
    move 50 steps
    turn ↻ 90 degrees
pen up
```

This code can be defined as a procedure that can be called whenever it is needed.



```
define Square
pen down
repeat 4
    move 50 steps
    turn ↻ 90 degrees
pen up
```



```
when 🏴 clicked
Square
```

So instead of considering a series of issues or commands, the problem has been simplified to one procedure without all the unnecessary details that have been hidden.

Decomposition and abstraction are two ways of computational thinking that are used to analyse complex problems. Computational thinking allows us to understand a complex problem and present our analysis in a way that a human being can use to create a computerised solution.

Variables

In computer programming, a variable may be required to store data that can change. Variables are given identifiers (names) that should reflect the data being stored in them. An example of a variable is txt_FirstName. This variable has a **self-documenting identifier**, which implies the type of data being stored in it is text containing a person's first name.

Constants

Constants are used in computer programming to store data that does not change. Constants are also given self-documenting identifiers that should reflect the data being stored in them. An example of a constant would be Pi = 3.14, as this is a self-documenting identifier that does not change. A constant is usually written in capitals, e.g. 'BOILING_POINT_OF_WATER = 100' as the boiling point of water never changes.

Local and global variables

A **local** variable is a variable that is defined within a sub-procedure and as such is only accessible from within that same sub-procedure. This is known as its scope. A **global** variable is a variable that has a larger scope as it is defined globally and is therefore accessible from anywhere within a program. The advantage of defining a local variable over a global variable is that it is easier to track the changes to a variable, and the reason for the changes when it is only used within a sub-procedure. An advantage of defining a global variable over a local variable is that sometimes it can be the most efficient way of ensuring that an important piece of data is accessible to all sub-procedures, e.g. the details of the user currently logged into a program.

Below is an example of an algorithm that calculates the area of a circle:

```
 1  Pi = 3.142
 2  Radius is real
 3
 4  declare subprocedure FindArea {procedure to calculate the area fo a circle}
 5  Area is real
 6
 7  start
 8      Area = PI * Radius * Radius
 9  end
10
11  startmainprog
12      output "Type in the radius"
13      input Radius
14
15      call FindArea
16
17      output "The area is ", Area
18  endmainprog
19
```

An example of a global variable here is *Radius* as it can be accessed throughout the entire program. An example of a local variable is *Area*. It is a local variable as it has been defined within the sub-procedure called *FindArea*.

Can you spot the error with the following line from the algorithm above?

```
17     output "The area is ", Area
```

How would you amend the algorithm to correct this problem?

Static and dynamic variables

Each time a program is run, **static** variables are stored in a location in memory and have a lifespan that lasts the entire time that program is running. For example, if you assign the number 2.14 to a static variable (and do not change it), the static variable will still contain 2.14 the next time you run the sub-procedure and until the whole program stops running.

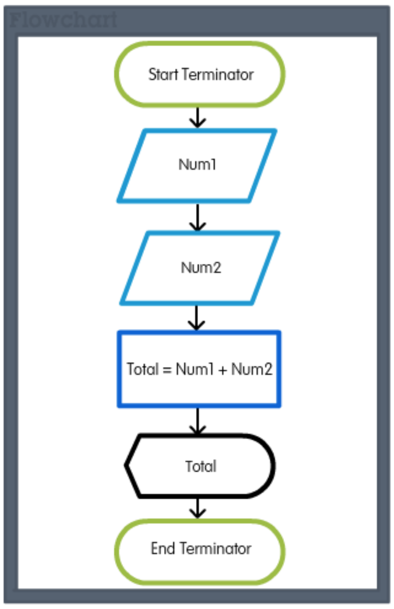
Each time a dynamic variable is defined, it is assigned a new location in memory and has a lifespan that ends when the sub-procedure in which it was defined ends. For example, if you assign the number 2.14 to a dynamic variable in a sub-procedure (and do not change it) and the sub-procedure ends, the next time you run that sub-procedure, the dynamic variable will no longer contain any value.

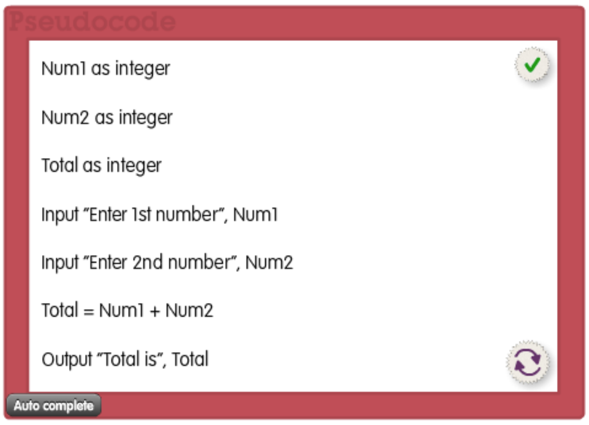
2. Algorithms and programming constructs

In programming, an algorithm is a set of instructions that can be used to solve a given problem. The instructions must be clear and in the correct order to produce the solution. These instructions will be the starting point for writing a computer program to solve the given problem.

An algorithm should not be in computer code. It should be presented in a way that it can be used in different programming languages. We are going to present algorithms as pseudo code or flowcharts. Pseudo code is a way of writing instructions in plain English. A flowchart is a diagram showing the instructions to be carried out in the order they should be carried out.

Here is an algorithm to add together two numbers and output their total shown as a flowchart and in pseudo code.





```
Num1 as integer
Num2 as integer
Total as integer
Input "Enter 1st number", Num1
Input "Enter 2nd number", Num2
Total = Num1 + Num2
Output "Total is", Total
```

A good algorithm should:

- be finite – if an algorithm never ends trying to solve the problem, it is not going to be of use
- have well defined instructions – each step of the algorithm should be clear so that it can be carried out exactly as intended
- be effective – the algorithm should give the correct result/solution to the problem.

We are going to use the following rules for pseudo code and flow charts.

Construct	Example usage

Declare subroutines	`Declare CapitalLetterOfName`
	`End Subroutine`

Call a subroutine	`call SubroutineNeeded`
Declare and use arrays	`myarray[99]`
Literal outputs	`output “Please enter a number"`
Variable names	`myvariable`
Define variable data type	`myvariable is integer`

Data types	`integer, character, string,`
	`Boolean, real`

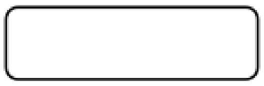
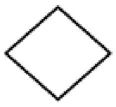
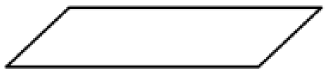
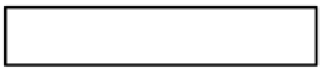
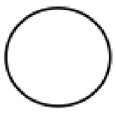
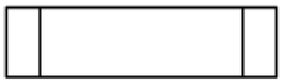
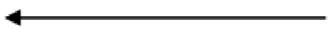
Assignment	`set counter = 0`
Selection	`if … else … end if`

Indent at least single space after if or do or repeat etc.	`if counter = 1`
	`   output counter`
	`end if`

Annotation	`{some annotation goes here}`
Comments (for Java only)	`/** Comments for Java */`

Repetition	`for i … next i`
	`repeat … until`
	`do … loop`
	`do …while`
	`while … repeat`

Algorithms represented using a flowchart will use the following convention:

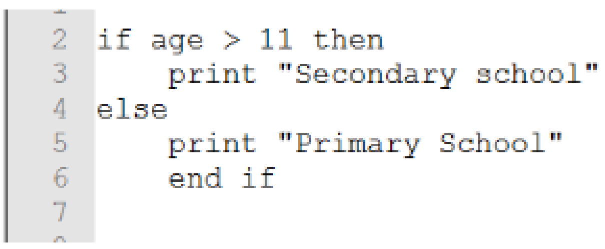
Start/Stop procedure	
Decision box	
Input/Output	
Operation	
Connector	
Store/Subroutine call	
Flow of control (Arrowhead indicates direction of flow)	

Sequence, selection and iteration

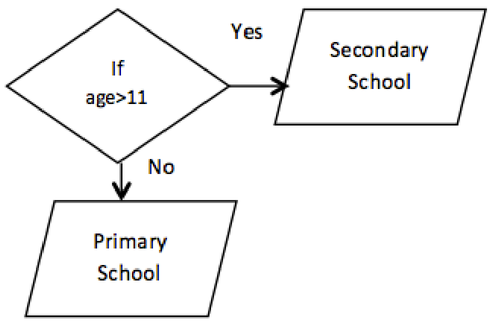
These are the three basic constructs we use to design algorithms.

Algorithms consist of a series of instructions in a specific order. This is the order or **sequence** in which the instructions must be carried out for the algorithm to work. A computer can only follow instructions in the order they are given. If the sequence is not right the computer will still follow the order in which the instructions are given.

A **selection** instruction is one where a decision must be made. There are times when an instruction in an algorithm may give different options.

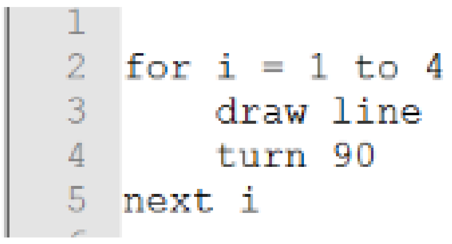


```
if age > 11 then
    print "Secondary school"
else
    print "Primary School"
    end if
```

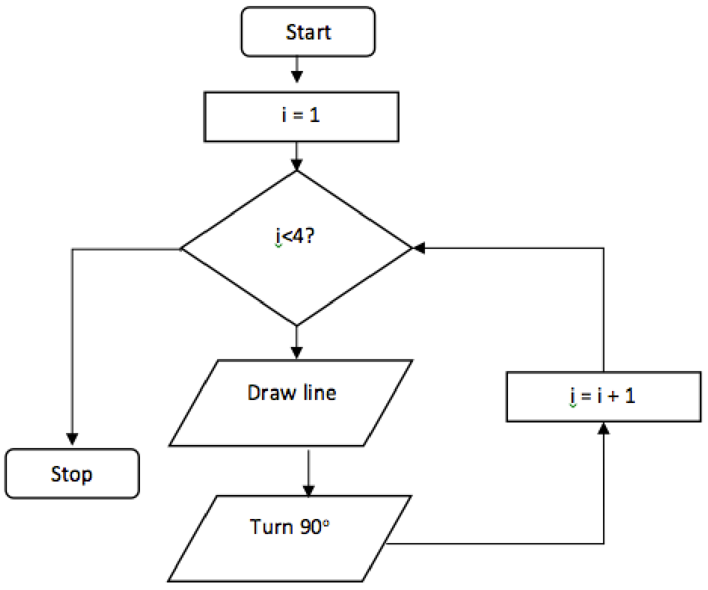


Sometimes an algorithm will require a set of steps to be carried out more than once or many times. This is called **iteration** and often referred to as a loop in the program.

If we want a program to repeat a set of two instructions four times we can use a ‘for i…next’ loop.



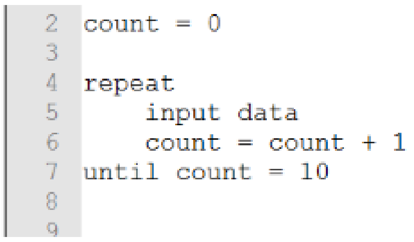
```
for i = 1 to 4
    draw line
    turn 90
next i
```



Using count and rogue values with loops

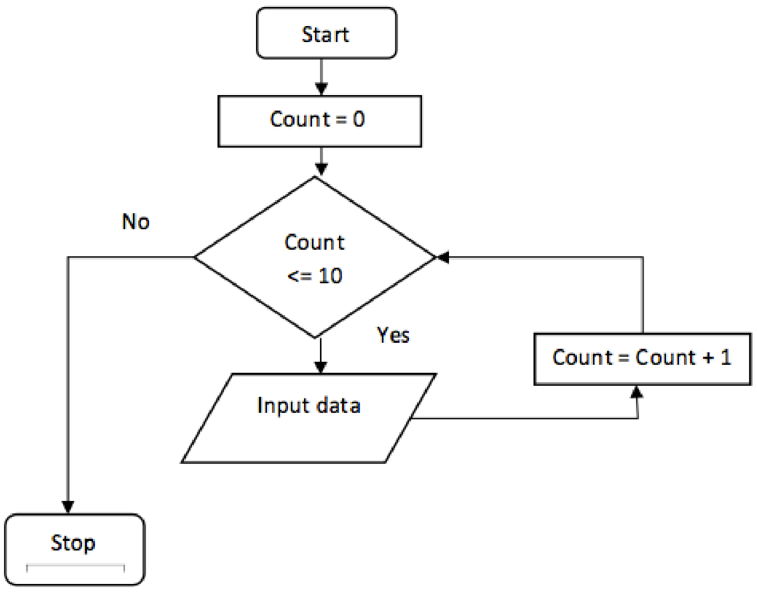
All loops must eventually be terminated. Sometimes we won't know how many times we will need the instructions in the loop to be used. If this is the case, we can control the program by using a count or rogue value.

A count will record the number of times a process is carried out. When the count reaches the required number, the loop will terminate.

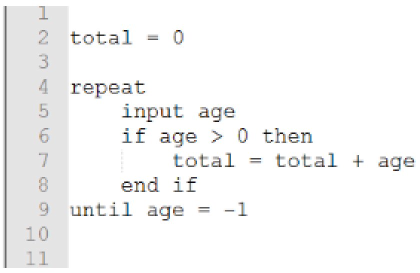


```
count = 0

repeat
    input data
    count = count + 1
until count = 10
```



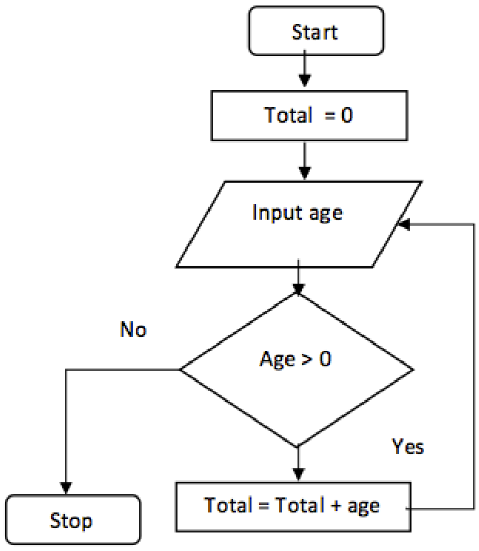
A rogue value is a value that falls outside the range of possible values for the data being processed. If we were calculating the average age of a class of children, we could set a rogue value of -1 to stop the loop as no child can have a negative age.



```

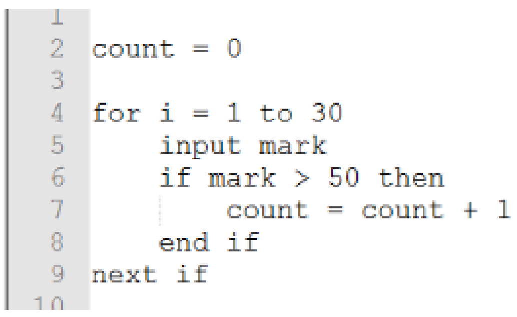
total = 0

repeat
    input age
    if age > 0 then
        total = total + age
    end if
until age = -1
```



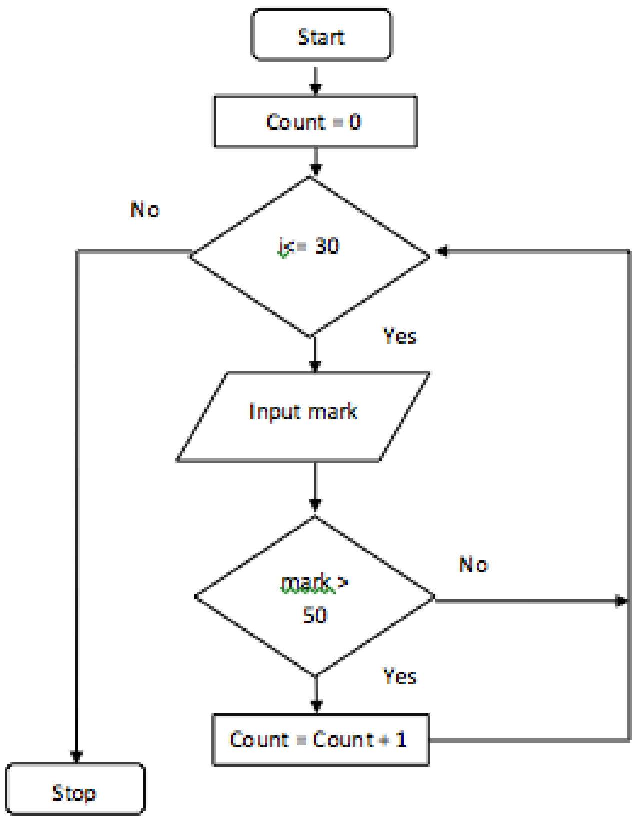
Why is the ‘if . . .then’ statement included in the algorithm?
A count can also be used to check whether a condition has been met.

A set of 30 test results is to be entered into a program. Each time the program is run the teacher wants to know how many pupils had marks over 50.



```
count = 0

for i = 1 to 30
    input mark
    if mark > 50 then
        count = count + 1
    end if
next if
```



String handling

We are going to use the following rules in relation to pseudo code for string handling.

Construct	Example usage
Variable names	`myvariable`
Define variable as string	`myvariable is String`
Length of string	`len (string)`
Mid string where x is the offset and y is the length	`mid (string, start, length)`
Replace part of a string	`replace (string, find, replacewith)`
Compare two strings	`str(Comp (string1, string2)`

Creating strings

To create a string, we need to define a variable as a string and assign a value to the variable.

```
greeting is String
greeting = "Hello from me!"
print greeting

Hello from me!
```

Measuring the length of a string

To find out how many characters are in a string, we use the 'len' command. Any keyboard stroke is counted as a character so spaces and special characters like an exclamation mark are counted as well as letters and numbers.

```
greeting is String
greeting = "Hello from me!"
length = len(greeting)
print length

13
```

Returning all or part of a string

To discover the contents of all or part of a string, we have to use the ‘mid’ command. Normally you would use the ‘len’ command to find out how long the string is before you would use the ‘mid’ command.

```
txt is String
partMessage is String
txt = “Have a happy birthday”
partMessage = mid(txt, 8, 5)
print partMessage

happy
```

Replacing part of a string

To replace part of a string you need to use the ‘replace’ command.

```
txt is String
message is String
txt = “Have a happy birthday”
message = replace(txt, “happy”, “fantastic”)
print message

Have a fantastic birthday
```

```
txt is String
message is String
txt = “Have a happy birthday”
message = replace(txt, “a”, “xx”)
print message

Hxxve xx fxxntxxstic birthdxxy
```

Comparing two strings

To compare the contents of two strings, we use the ‘str(Compare’ command. This command will return a value of 0 (true) if the two strings are identical and a value of -1 (false) if they are not.

```
txt1 is String
txt2 is String
response = Integer
txt1 = “Hello”
txt2 = “Hello”
response = str(Compare, txt1, txt2)
print response

0
```

Sometimes we just want to compare whether the content is identical, and not the use of upper and lower case letters. We can add another parameter (1) to the ‘str(Compare’ command to carry out a textual comparison.

```
txt1 is String
txt2 is String
response = Integer
txt1 = “Hello”
txt2 = “hello”
response = str(Compare, txt1, txt2,1)
print response

1
```

Joining strings together and adding text

The process of combining a string with text or combining two strings with or without additional text is called concatenation. The example below combines someone's first name and surname with a welcome message.

```
txt1 is String
txt2 is String
concatString is String
txt1 = "Sarah"
txt2 = "Smith"
print "Welcome " & txt1 & txt2

Welcome Sarah Smith
```

Sorting

A sorting algorithm will sort items in a list into a particular order, which may be alphabetic or numeric. As sorting a large list of items can be timely, computer algorithms have been developed to do the work for us.

INTERESTING FACT
Data takes the longest to sort when it is in the reverse order of the order required. For example if data is sorted into ascending order when it needs to be sorted into descending order.

Merge Sort

The merge sort is a sorting technique based on the idea of 'divide and conquer'. A merge sort first divides a list into two equal halves and then combines them in a sorted list.

To understand how the merge sort works we will use a merge sort algorithm to sort the following list:

37	14	10	27	24	19	44	35

We need to divide the list into two equal halves.

37	14	10	27

24	19	44	35

We then split the halves in half.

37	14

10	27

24	19

44	35

We keep dividing the list until each list is a single item.

37	14	10	27	24	19	44	35

We then combine them in the same way they were divided but in order.

14	37	10	27	19	24	35	44

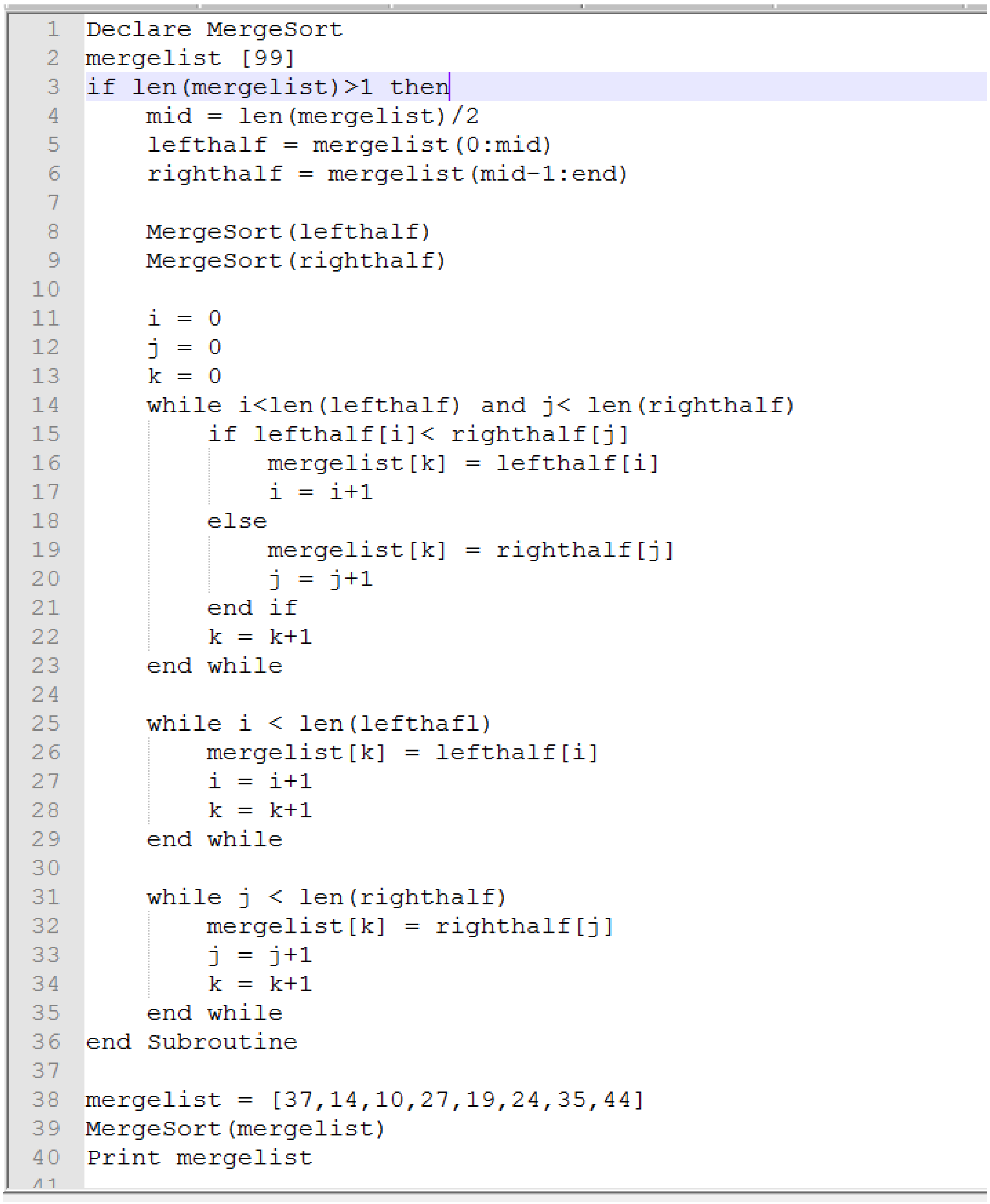
In the next move (iteration) we combine the lists to make lists of 4 sorted items.

10	14	27	37	19	24	35	44

After the final iteration the list should be fully sorted.

10	14	19	24	27	35	37	44

The merge sort algorithm



```
Declare MergeSort
mergelist [99]
if len(mergelist)>1 then
    mid = len(mergelist)/2
    lefthalf = mergelist(0:mid)
    righthalf = mergelist(mid-1:end)

    MergeSort(lefthalf)
    MergeSort(righthalf)

    i = 0
    j = 0
    k = 0
    while i<len(lefthalf) and j< len(righthalf)
        if lefthalf[i]< righthalf[j]
            mergelist[k] = lefthalf[i]
            i = i+1
        else
            mergelist[k] = righthalf[j]
            j = j+1
        end if
        k = k+1
    end while

    while i < len(lefthafl)
        mergelist[k] = lefthalf[i]
        i = i+1
        k = k+1
    end while

    while j < len(righthalf)
        mergelist[k] = righthalf[j]
        j = j+1
        k = k+1
    end while
end Subroutine

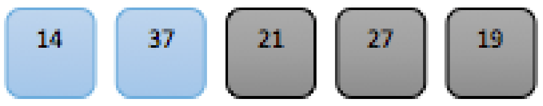
mergelist = [37,14,10,27,19,24,35,44]
MergeSort(mergelist)
Print mergelist
```

The bubble sort

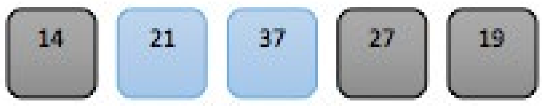
The bubble sort is a simple sorting algorithm. The algorithm is based on the comparison of adjacent data items, swapping them if they are not in the correct order. The bubble sort is not suitable for large sets of data.

How the bubble sort works

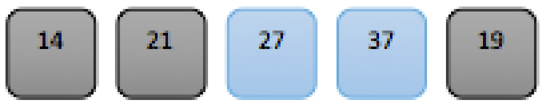
The bubble sort starts with comparing the first two items, in this case 37 and 14. They are out of order so they need to be swapped over.



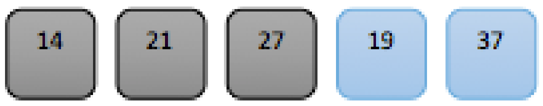
Next we compare the 37 with 21. These two items need to be swapped.



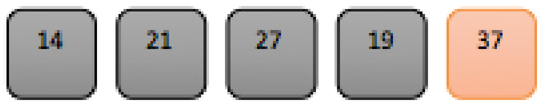
Now we compare 37 with 27. Again these two items need to be swapped.



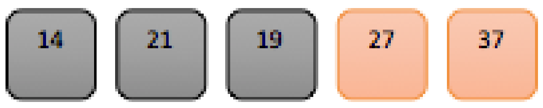
Comparing 37 with 19 means that the two items need to be swapped again.



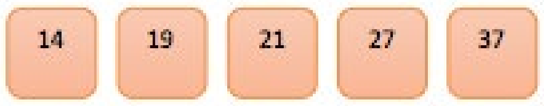
After the first set of comparisons, know as an iteration, the list looks like this:



After the second iteration it will look like this:

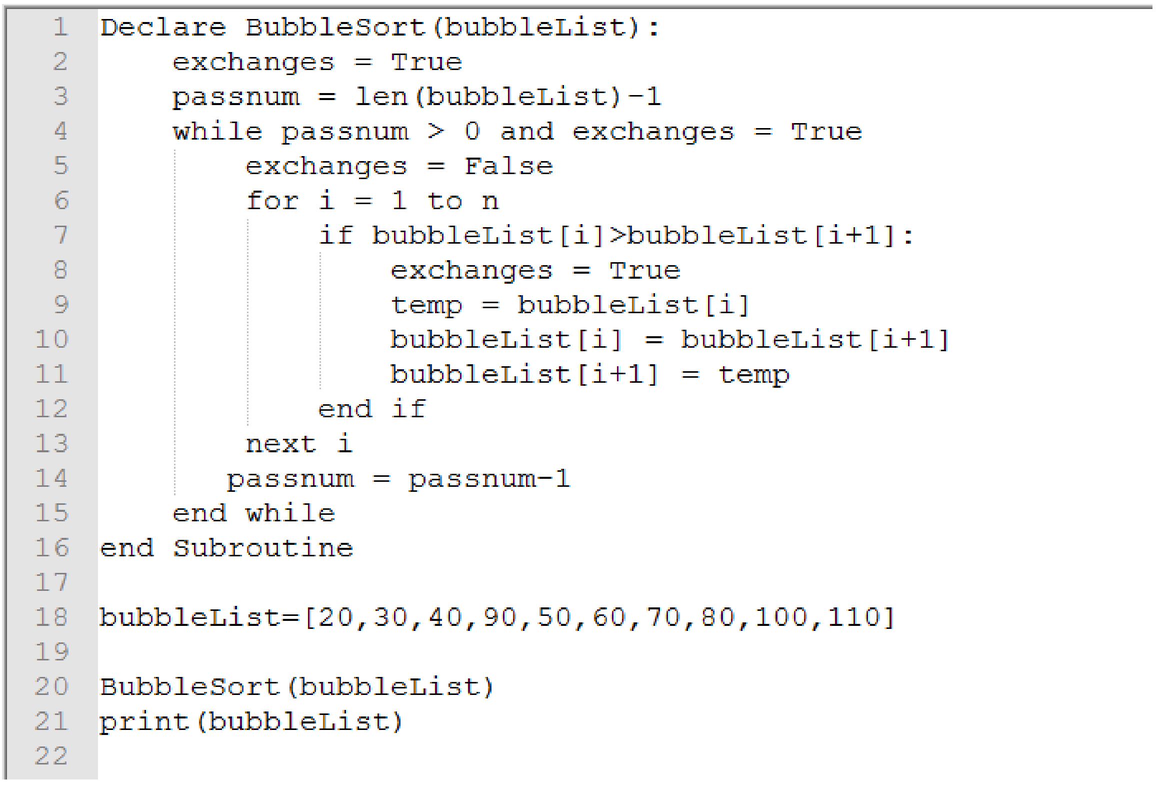


Notice that after each iteration at least one item has moved to the correct position. After the third iteration the list will look like this.



When an iteration results in no swaps being needed, the bubble sort is stopped.

The bubble sort algorithm



```
Declare BubbleSort(bubbleList):
    exchanges = True
    passnum = len(bubbleList)-1
    while passnum > 0 and exchanges = True
        exchanges = False
        for i = 1 to n
            if bubbleList[i]>bubbleList[i+1]:
                exchanges = True
                temp = bubbleList[i]
                bubbleList[i] = bubbleList[i+1]
                bubbleList[i+1] = temp
            end if
        next i
       passnum = passnum-1
    end while
end Subroutine

bubbleList=[20,30,40,90,50,60,70,80,100,110]

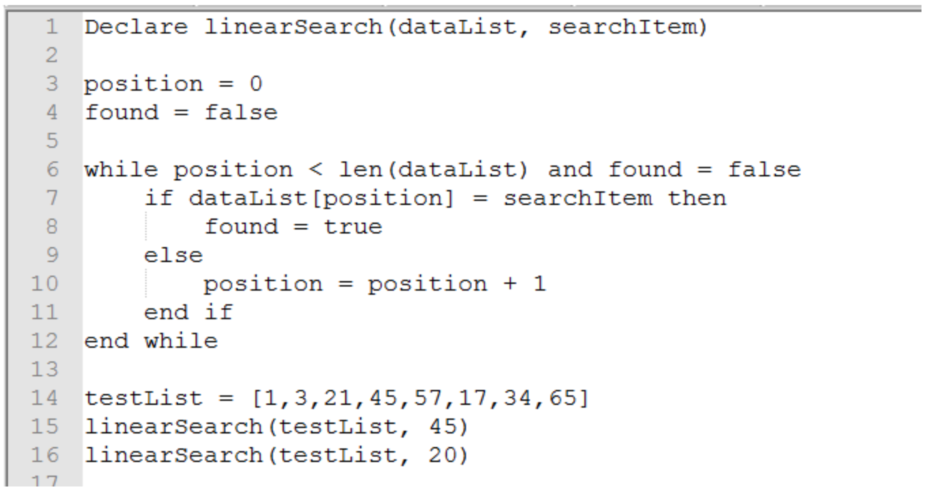
BubbleSort(bubbleList)
print(bubbleList)
```

Searching

Searching for data is one of the basic operations of computing.

Linear search

The linear search is a very simple search algorithm. Each item in the data set is compared with the search condition in sequence until the item is found or the end of the data set is reached. As the items are compared in sequence the linear search is sometimes known as the sequential search. The items in the list are not in any particular order within the data set.



```
 1  Declare linearSearch(dataList, searchItem)
 2
 3  position = 0
 4  found = false
 5
 6  while position < len(dataList) and found = false
 7      if dataList[position] = searchItem then
 8          found = true
 9      else
10          position = position + 1
11      end if
12  end while
13
14  testList = [1,3,21,45,57,17,34,65]
15  linearSearch(testList, 45)
16  linearSearch(testList, 20)
```

The test data included at line 15 would produce a successful search for the search item '45'. The test data at line 16 would be unsuccessful as the search item '20' is not included in the test data.

The linear search is not an efficient search. We can measure the efficiency of a search by considering the number of comparisons that are made before the required item is found. The items in the list are not ordered so the probability that the item we are looking for is in any particular position is exactly the same for each position in the list. This means that we may have to compare every item before we find the required one in the last position. We would also have to search the entire list before we discovered that the item was not included in the list.

Binary search

A more efficient method of searching a list of data is an algorithm known as the binary search.

For a search to be more efficient it is necessary to sort the data into order. Once the data is in order you can adopt methods that would not work on unordered data. Rather than starting the search at the beginning of the list, the search starts at the mid point of the list. The data item is compared with the search item, with three possible outcomes:

- the item at the mid point will match the search item
- the search item will be less than the item at the mid point
- the search item will be greater than the item at the mid point.

If the search item is less than the item at mid point, then all the items after the mid point can be ignored. Similarly if the search item is greater than the mid point then the first half of the list can be discarded.

This process is then repeated on the remaining data time after time until the required item is found.

This list has been sorted. We are going to search the list for the number 31.

11	17	19	23	29	31	37	41	43
0	1	2	3	4	5	6	7	8

To calculate the mid point we use this formula:

mid point = low + (high – low)/2
mid point = 0 + (8 – 0)/2
mid point = 4

With the mid point being 4, we need to compare our search item (31) with the data at position 4 (29).

The search item is greater than the data at position 4, so we can discard the first part of the list.

11	17	19	23	29	31	37	41	43
0	1	2	3	4	5	6	7	8

We need to recalculate the mid point:

mid point = 5 + (8 – 5)/2
mid point = 6.5

In this situation, the mid point is taken as the integer part of the result, so the mid point will be 6.

The search item is less than the data item at position 6 so we can discard the list from the mid point upwards.

11	17	19	23	29	31	37	41	43
0	1	2	3	4	5	6	7	8

When we recalculate the mid point:

mid point = 5 + (5 – 5)/2
mid point = 5

The search item is now equal to the item at position 5. We have had to make 3 comparisons to find the required data. This is far more efficient than a linear search. It is important to remember that our examples have limited data. If you were searching through thousands of data items, the difference between the two methods would be significant.

The binary search algorithm

```
Declare binarySearch(dataList, searchItem):
    if len(dataList) = 0
        return False
    else
        midpoint = low + (high - low)/2
    end if
    if dataList[midpoint]= searchItem
            return True
    else:
        if item < dataList[midpoint]:
                return binarySearch(dataList[low:midpoint],searchItemtem)
        else:
            return binarySearch(dataList[midpoint+1:high],searchItem)
        end if
    end if

    testlist = [11,17,19,23,29,31,37,41,43]
    print(binarySearch(testlist, 23))
    print(binarySearch(testlist, 13))


```

3. Programming languages

HyperText Markup Language (HTML)

Why HTML is important as a standard for web page creation
HTML is a standard used when creating web pages.

Web standards, such as HTML, are important in order to simplify the development of web pages, so web programmers will be able to understand another developer's code. It is also important for the end users of web pages, as following standards ensures that different web browsers are able to display web pages in the way in which they were intended.

Use of HTML tags and their closures
HTML tags commonly come in pairs, such as <html> and </html> or <b> and </b>. The first tag in a pair is called the opening tag and the second tag is called the closing tag. Between these tags, programmers can add text, more tags, comments and other types of text-based content.

INTERESTING FACT
Browser use statistics (December 2018)

- Chrome 62.9%
- Internet Explorer and Edge 7.1%
- Firefox 6.2%
- Safari 14.3%
- Opera 3.0%

The purpose of a web browser, such as Internet Explorer, Google Chrome and Safari is to read HTML code and render it on screen. The browser does not display the HTML tags, but instead uses the tags to interpret the content of the page.

- The text between the <html> and </html> tags describes the web page.
- The <head> element is a container for all the head elements. The head elements can include a title for the document, scripts, styles and meta information.
- Meta elements are used to describe the page, including key words, author of the document and when the document was last altered.
- The text between <body> and </body> tags includes the contents of the web page.
- The <p> tag defines a paragraph. Web browsers will automatically add some space before and after each <p> element.
- When an element within a web page is hyperlinked, it is placed within the <a href="url"> and </a> tags.
  For example, <a href="http://www.wjec.co.uk">WJEC</a> will be displayed as WJEC.
- The <img> tag is slightly different, as it does not contain a closing tag. For example, <img src="logo.gif"> will display the image file logo.gif.

The table below shows how unformatted text will look when placed within the commonly used formatting tags.

Command	Opening tag	Closing tag	Unformatted text	Formatted text
Headings	<h1> to <h6>	</h1> to </h6>	`Computer science`	**Computer science**
Bold	<b>	</b>	`Computer science`	**Computer science**
Italic	<i>	</i>	`Computer science`	*Computer science*
Centre align	<center>	</center>	`Computer science`	Computer science

Bulleted list

To create a list of bullet points, we need to use the tag for an unordered list, <ul>. For each line, in the list we use the <li> tag.

For example:

```
<ul>
     <li>Apples</li>
     <li>Oranges</li>
     <li>Pears</li>
</ul>
```

will display as:

- Apples
- Oranges
- Pears

Blockquote

The Blockquote tag is used to specify a section that is quoted from another source. Web browsers indent <blockquote> elements.

The horizontal rule tag, <hr>, is used to separate content in an HTML page.

For example:

```
     <h2>HTML</h2>
     <p> We use HTML to control the way a web page looks</p>
     <hr>
     <h3>XHTML</h3>
     <p>XHTML stands for eXtensible HyperText Markup
Language</p>
```

will display as:

HTML

We use HTML to control the way a web page looks

XHTML

XHTML stands for eXtensible HyperText Markup Language

Here is an example of how original text is formatted using HTML tags.

Original text

For Sale

Bluetooth Hands Free Car Kit

Make calls without wearing a headset with this Bluetooth v1.2 EDF Multipoint Hands-free Speakerphone! Visit www.edfweb.com to see. Simply pair this device to any Bluetooth enabled phone and talk hands-free today!

HTML

```
<html>

<body>

<h1><center>For Sale</center></h1>

<p> <b>Bluetooth Hands Free Car Kit</b></p>

<p>Make calls without wearing a headset with this Bluetooth
v1.2 EDF Multipoint Hands-free Speakerphone!</p>

<p>Visit <a href="http://www.edfweb.com/”>www.edfweb.com</a> to
see.</p>

<p><i> Simply pair this device to any Bluetooth enabled phone
and talk hands-free today! </i></p>

</body>

</html>
```

Formatted web page

For Sale

Bluetooth Hands Free Car Kit

Make calls without wearing a headset with this Bluetooth v1.2 EDF Multipoint Hands-free Speakerphone!

Visit www.edfweb.com to see.

Simply pair this device to any Bluetooth enabled phone and talk hands-free today!

Assembly Language

Assembly language is a programming language that is once removed from machine code. Machine code is made up of 0s and 1s and is extremely difficult for a programmer to use. Assembly language has the same structure and instruction set as the commands in machine code but they use mnemonics (names) rather than binary code.

PYTHON
VB.NET
HIGH-LEVEL
LANGUAGE
ASSEMBLY
LANGUAGE
MACHINE CODE

HARDWARE

Each type of computer has its own machine code and assembly language. This means that a program written in machine code for one CPU will not run on another type of CPU.

Computer programs were INITIALLY all written in low-level languages, but over time, high-level languages have been developed that are closer to written English and easier to use.

However, assembly language programs:

- require less memory and execution time
- allow code to interact directly with hardware, such as device drivers
- are suitable for time-critical processes.

Instruction	Mnemonic	What does it do?
Input	`INP`	Inputs a value and stores it in the accumulator
Output	`OUT`	Displays the contents of the accumulator
Store	`STA`	Transfers a number from the accumulator to RAM
Load	`LDA`	Transfers a number from RAM to the accumulator
Add	`ADD`	Adds the contents of the accumulator to the contents of a RAM address
Subtract	`SUB`	Subtracts the contents of the accumulator from the contents of a RAM address
Branch	`BRA`	Jumps to the RAM location specified – used for loops
End/Stop/Halt	`HLT`	Stops the processor
Data definition	`DAT`	Defines variables

Some example programs

This is an assembly language program to add together two numbers.

```
INP                 ‘input a number
STA 99              ‘store the number in memory slot 99
INP                 ‘input a number
ADD 99              ‘add this number to the number stored in memory slot 99
OUT                 ‘output the result of the addition
HLT                 ‘halt/stop/end
```

This is an assembly language program for subtraction.

```
INP                 ‘input a number
STA first           ‘store the number in a variable called 'first'
INP                 ‘input a number
STA second          ‘store the number in a variable called 'second'
LDA first           ‘load the number in the 'first' variable into the accumulator
SUB second          ‘subtract the contents of the 'second' variable from the accumulator
OUT                 ‘output the number in the accumulator
first DAT           ‘declare 'first' as a variable
second DAT          ‘declare 'second' as a variable
```

Object oriented programming

Object oriented programming (OOP) can be viewed as a collection of objects that communicate with each other.

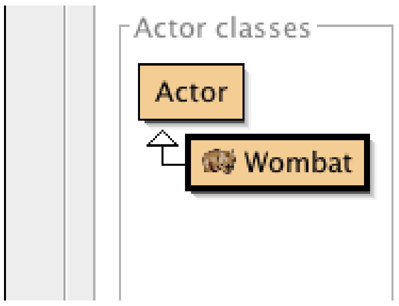
To understand OOP we need to know about objects, classes, methods and instance variables.

Object – an object has states and behaviours. Let’s think about the little wombat from Greenfoot.

The wombat has states, i.e. a name and breed.

It also has behaviours, i.e. grunting, burrowing and moving.

Class – a class is used to describe one or more objects. The class is a plan or template for creating objects within a program. Each object is created from a single class but a class can be used to create many objects. Each wombat in a scenario will be a class instance (object).



Class names must always begin with an uppercase letter.

Methods – a method is a behaviour. One class can contain many methods such as the wombat grunting, burrowing and moving. Method names must always begin with a lowercase letter.

Instance variables – these are variables that are bound to class instances. Imagine that you have created a Greenfoot game in which wombats eat leaves. Each wombat will have an instance variable called leaves. This variable will record how many leaves each wombat has eaten. Wombat1 could have eaten 4 leaves and Wombat2, 6 leaves. These are both values of the instance variable but independent of each other.

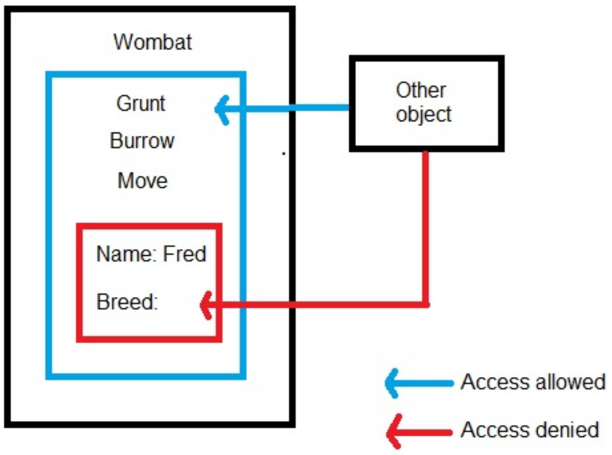
Properties of OOP languages

OOP languages have four main properties that reduce the amount of code required in a program. They are:

- **Encapsulation** – the process of wrapping data and the code that operates on it into a single entity. The variables and methods are wrapped up inside the class.

- **Abstraction** – the process of hiding non-essential features and showing the essential features.

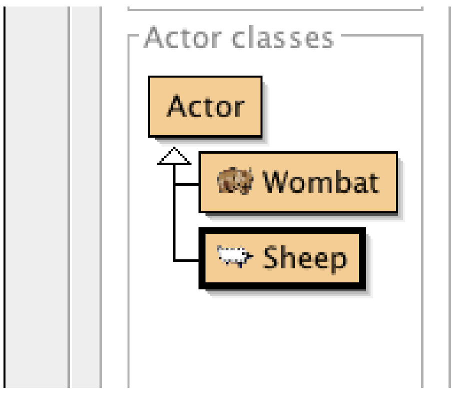
  The wombat's states are hidden from other objects but its behaviours are not.



- **Inheritance** – this allows a new class to use the properties and methods of another existing class. The new (derived) class inherits the states and behaviours of the existing (base) class. The derived class is also called the subclass and the base class is called the superclass. In our example, Actor is the superclass and Wombat is the subclass.

  The subclass can have its own variables and methods in addition to those inherited from the superclass. A superclass can have many subclasses but a subclass can inherit from only one superclass.

- **Polymorphism** – this concept allows actions to act differently based on the object performing the action.

  One of the wombat's behaviours or actions is to grunt when it makes a sound. We will call this action makeSound(). The sheep will bleat (Baaaa!!) when it makes a sound. We can also call this action makeSound(). The makeSound() action makes the wombat object grunt and the sheep object bleat. The action acts differently depending on the object.

WHAT DO YOU NEED TO BE ABLE TO CODE IN GREENFOOT?

You should be able to:

- create new classes and extend existing classes
- create new objects and edit existing objects
- create new worlds and edit existing worlds
- write and invoke methods
- change existing methods
- create new properties and edit existing properties (including public, private, static, etc.)
- add and remove objects from worlds
- use actors
- move objects around a world
- keyboard input
- add and play sounds
- implement and use parameter passing (by value and by reference)
- access one object from another
- implement object collision detection
- implement random number generation
- use the concept of inheritance and encapsulation.

You must use version 2.4.2

4. Data structures and data types

USING DATA STRUCTURES AND DATA TYPES

You should be able to:

- Create new data structures including:-
  - one-dimensional arrays
  - two-dimensional arrays
  - files and records.
- Implement data types including:-
  - Integer
  - Boolean
  - Real
  - Character
  - String.
- Assign, identify and explain the use of constants and variables in algorithms and programs.
- Describe the scope and lifetime of variables in algorithms and programs.

5. Security and authentication

USING SECURITY TECHNIQUES

You should be able to:

- Use appropriate security techniques such as usernames and passwords in algorithms and programs.
- Use appropriate authentication techniques.